UNITED STATES PATENT AND TRADEMARK OFFICE
DOCUMENT CLASSIFICATION BARCODE SHEET

000

CATEGORY:

CLEARED

ADDRESS
CONTACT IF FOUND:

414 Rec'd PCT/PTO 01 DEC 2000

FORM PTO-1390 (REV 10-94)

U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 10873.593USWO

U S APPLICATION NO (If known, see 37 C F R 1 5): Unknown 09/701754

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP00/02910	May 31,1999	June 1, 1998

TITLE OF INVENTION

ZOOM LENS AND VIDEO CAMERA COMPRISING THE SAME

APPLICANT(S) FOR DO/EO/US

YAMADA et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(l).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [X] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US)
6. [X] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [X] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [X] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [X] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. [X] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [X] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
    [ ] A SECOND of SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information: PCT/IB/338; PCT/IB/304; PCT/IB/308; Written Amendment based on Section 11; Written Reply; Replacement pages 1-8; International Search Report; International Preliminary Examination Report

525 Rec'd PCT/PTO 01 DEC 2000

U.S. APPLICATION NO (If known, see 37 C F R 1 5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
Unknown 09/701754	PCT/JP00/02910	10873.593USWO

17. [X] The following fees are submitted:

CALCULATIONS PTO USE ONLY

BASIC NATIONAL FEE (37 CFR 1.492(a) (1)-(5)):

Search Report has been prepared by the EPO or JPO....................**$860.00**

International preliminary examination fee paid to U.S. Patent and Trademark Office (37 CFR 1.492(a)(1))....................**$690.00**

No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))....................**$710.00**

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(3)) paid to USPTO....................**$1000.00**

International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)....................**$100.00**

				CALCULATIONS	PTO USE ONLY
ENTER APPROPRIATE BASIC FEE AMOUNT =				**$860.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				**$0**	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	27 -20 =	7	X **$18.00**	**$126.00**	
Independent claims	7 -3 =	4	X **$80.00**	**$320.00**	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$270.00**	**$0**	
TOTAL OF ABOVE CALCULATIONS =				**$1306.00**	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28).				**$0**	
SUBTOTAL =				**$1306.00**	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f). +				**$0**	
TOTAL NATIONAL FEE =				**$1306.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				**$40.00**	
TOTAL FEES ENCLOSED =				**$1346.00**	
				Amount to be: refunded	**$0**
				charged	**$0**

a. [X] Check(s) in the amount of $1306.00 and $40.00 to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. ________________ in the amount of $ ____________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 13-2725.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO
Douglas P. Mueller
MERCHANT & GOULD
P.O. Box 2903
Minneapolis, MN 55402-0903

SIGNATURE

NAME Douglas P. Mueller

REGISTRATION NUMBER 30,300

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE 01 DEC 2000

09/701754

Applicant: YAMADA et al.

Docket: 10873.593USWO

Title: ZOOM LENS AND VIDEO CAMERA COMPRISING THE SAME

CERTIFICATE UNDER 37 CFR 1 10
'Express Mail' mailing label number: EL649974777US
Date of Deposit. December 1, 2000
I hereby certify that this paper or fee is being deposited with the United States Postal Service 'Express Mail Post Office To Addressee' service under 37 CFR 1 10 and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231
By Chatia Lambert
Name. Chatia Lambert

BOX PCT
Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

We are transmitting herewith the attached:

- ☒ Transmittal sheet, in duplicate, containing Certificate under 37 CFR 1.10.
- ☒ National Stage PCT Patent Application: Spec. 88 pgs; 29 claims; Abstract 1 pg. The fee has been calculated as shown below in the 'Claims as Filed' table.
- ☒ 94 sheets of formal drawings
- ☒ A signed Combined Declaration and Power of Attorney
- ☒ Assignment of the invention to Matsushita Electric Industrial Co., Ltd., Recordation Form Cover Sheet
- ☒ A check in the amount of $1306.00 to cover the Filing Fee
- ☒ A check for $40.00 to cover the Assignment Recording Fee.
- ☒ Other: PTO-1390; Preliminary Amendment; Article 19 Amendments; PCT/IB/304; PCT/IB/308; Replacement pages 1-8; Written Reply; Written Amendment; International Preliminary Examination Report and translation; International Search Report; PCT/IB/338; PCT application as filed
- ☒ Return postcard

CLAIMS AS FILED

Number of Claims Filed		In Excess of:		Number Extra		Rate		Fee
Basic Filing Fee								$860.00
Total Claims								
27	-	20	=	7	x	18.00	=	$126.00
Independent Claims								
7	-	3	=	4	x	80.00	=	$320.00
MULTIPLE DEPENDENT CLAIM FEE								$0.00
TOTAL FILING FEE								$1306.00

Please charge any additional fees or credit overpayment to Deposit Account No. 13-2725. A duplicate of this sheet is enclosed.

MERCHANT & GOULD P.C.
P.O. Box 2903, Minneapolis, MN 55402-0903
(612) 332-5300

By:

Name: Douglas P. Mueller
Reg. No.: 30,300
Initials: DPM/tvm

23552
PATENT TRADEMARK OFFICE

(PTO TRANSMITTAL - NEW FILING)

09/701754

525 Rec'd PCT/PTO 01 DEC 2000

S/N Unknown PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	YAMADA et al.	Examiner:	Unknown
Serial No.:	Unknown	Group Art Unit:	Unknown
Filed:	December 1, 2000	Docket No.:	10873.593USWO
Title:	ZOOM LENS AND VIDEO CAMERA COMPRISING THE SAME		

CERTIFICATE UNDER 37 CFR 1.10
'Express Mail' mailing label number: EL649974777US
Date of Deposit: December 1, 2000
I hereby certify that this correspondence is being deposited with the United States Postal Service 'Express Mail Post Office To Addressee' service under 37 CFR 1.10 on the date indicated above and is addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.
By: Chatia Lambert
Name: Chatia Lambert

PRELIMINARY AMENDMENT

Box PCT
Assistant Commissioner for Patents
Washington, D. C. 20231

Dear Sir:

In connection with the above-identified application filed herewith, please enter the following preliminary amendment, which is based on the Article 19 and 34 amendments, based on claims amended in prosecution of the international application and published in the International Preliminary Examination Report, a copy of which is enclosed herewith:

IN THE SPECIFICATION

A courtesy copy of the present specification is enclosed herewith. However, the World Intellectual Property Office (WIPO) copy should be relied upon if it is already in the U.S. Patent Office.

Please amend the following sections:

Page 4, line 8, delete "1.05<R21/R20<2.5" and insert--1.05<R21/R20<2.0--

Page 9, line 25, delete "seventh embodiment" and insert--eighth embodiment--

Page 32, line 27, delete "2 to 4" and insert--7 to 9--

Page 35, line 13, delete "second lens group 61" and insert--second lens group 62--

Page 35, line 27, delete "first embodiment" and insert--sixth embodiment--

Page 38, line 18, delete "seventh embodiment" and insert--eighth embodiment--

Page 39, line 6, delete "fifth ans sixth embodiments" and insert--eighth embodiment--

Page 44, line 32, delete "sixth to tenth embodiments" and insert--sixth to ninth embodiments--

Page 48, line 8, delete "expressions (11) to (17)" and insert--expressions (11) to (14)--

Page 54, line 34, delete "fS/f34" and insert--f3/f34--

Page 62, line 7, delete "twelfth embodiment" and insert--thirteenth embodiment--

Page 62, line 26, delete "Expressions (6) to (18)" and insert--expressions (6) to (16)--

Page 65, line 19, delete "tenth embodiment" and insert--eleventh embodiment--

Page 66, line 20, delete "r31" and insert--rS1--

Page 68, line 22, delete "r39" and insert--rS9--

Page 69, line 17, delete "expressions (9) to (14)" and insert--expresions (8) to (14)

Page 72, line 1, delete "second lens group 62" and insert--second lens group 701--

Page 72, line 17, delete "expressions (12) to (19)" and insert--expressions (8) to (14)--

Page 72, line 27, delete "FIGs. 72-74 and FIGs. 7-9" and insert--FIGs. 71-73--

Page 73, line 17, delete "third lens group 63" and insert--third lens group 103--

Page 75, line 2, delete "Table 65" and insert--Table 66--

Page 75, line 23, delete "seventeenth embodiment" and insert--eighteenth embodiment--

Page 78, line 1, delete "102 becomes" and insert--142 becomes--

Page 81, line 30, delete "nineteenth embodiment" and insert--twentieth embodiment--

Page 83, line 5, delete "*blank in upper-left*" and insert--1--

Page 87, line 32, delete "twenty-first embodiment" and insert--twenty-second embodiment--

IN THE CLAIMS

Please amend the following claims as cited in the Article 19 and 34 Amendments:

Claim 12, lines 1 & 2, delete "any one of claims 1, 9, 10 or 11" and insert--claim 1--

Claim 29, lines 1 and 2, delete "any one of claims 13, 14, 16, 17, 20, 21, 22, 23 or 28" and insert--claim 13--

Claim 35, lines 1 and 2, delete "any one of claims 30 to 34" and insert--claim 30--

Claim 41, lines 1 and 2, delete "any one of claims 37 to 40" and insert--claim 37--

REMARKS

The above preliminary amendment is made to correct errors in the specification and to remove multiple dependencies from claims 12, 29, 35, and 41.

Applicants respectfully request that the preliminary amendment described herein be entered into the record prior to calculation of the filing fee and prior to examination and consideration of the above-identified application.

If a telephone conference would be helpful in resolving any issues concerning this communication, please contact Applicants' primary attorney-of record, Douglas P. Mueller (Reg. No. 30,300), at (612) 371.5237.

Respectfully submitted,

MERCHANT & GOULD P.C.
P.O. Box 2903
Minneapolis, Minnesota 55402-0903
(612) 332-5300

Dated: December 1, 2000

By ______________________
Douglas P. Mueller
Reg. No. 30,300

DPM/tvm

23552
PATENT TRADEMARK OFFICE

94 / prts

09/701754
525 Rec'd PCT/PTO 01 DEC 2000

DESCRIPTION

ZOOM LENS AND VIDEO CAMERA COMPRISING THE SAME

Technical Field

The present invention relates to a zoom lens used for a video camera or the like, and the zoom lens has a function optically to correct image movement caused by camera shake, vibration or the like.

Background Art

Motion picture cameras such as video cameras have been required to have a function to prevent vibration caused by camera shake, and various types of vibration-proof optical systems have been disclosed. For example, a zoom lens disclosed in JP-A-8-29737 includes an optical system consisting of two parts attached in front of the zoom lens in order to correct camera shake, where either of the parts is moved vertically to an optical axis in order to correct movement of images caused by camera shake.

A zoom lens disclosed in JP-A-7-128619 comprises four groups, where a part of the third lens group comprising plural lenses is moved vertically to the optical axis in order to correct the movement of images caused by camera shake.

However, the zoom lens disclosed in JP-A-8-29737 has an increased lens diameter for an optical system to correct camera shake for the purpose of attaching the optical system in front of the zoom lens. Accordingly, the entire component is upsized and a load on a driving system will be heavier. As a result, the zoom lens is unfavorable in view of downsizing, weight-reduction and power-saving.

The zoom lens disclosed in JP-A-7-128619 corrects image movement caused by camera shake by moving a part of the third lens group vertically to the optical axis while the same lens group is fixed with respect to the image plane. This type of zoom lens is more favorable than a zoom lens of front-attachment type in view of downsizing, but a load on the actuator will be heavier since the lens group for correcting camera shake is composed of three lenses.

Since an optical system for correcting camera shake is attached in front of the zoom lens disclosed in JP-A-8-29737, the lens diameter of the optical system will be increased, and the entire component will be upsized. So a load on the driving system will be heavier, and thus, this zoom lens is

unfavorable in view of downsizing, weight reduction and power-saving.

The latter zoom lens in JP-A-7-128619 is advantageous in downsizing and weight reduction when compared to a type comprising an optical system for correcting camera shake in front of the zoom lens, since a third lens group is fixed with respect to the image plane and a part thereof is moved vertically with respect to the optical axis. However, the zoom lens has a problem of deterioration in aberration, especially for chromatic aberration, when shifting lenses, since a part of the third lens group is moved.

Disclosure of Invention

A purpose of the present invention is to resolve the above mentioned problems in conventional zoom lenses by providing a small and compact zoom lens with less deterioration in the aberration performance and also a video camera using the same.

For this purpose, a first zoom lens of the present invention comprises a first lens group having a positive refracting power and being fixed with respect to an image plane, a second lens group having a negative refracting power and varying power by moving along an optical axis, a third lens group having a positive refracting power and being fixed with respect to the image plane, and a fourth lens group having a positive refracting power and moving along an optical axis so as to keep the image plane varied by a shift of the second lens group and an object at a predetermined position from a reference surface, and the first to the fourth lens group are disposed from the object in this order. The present invention is characterized in that the entire third lens group is moved vertically with respect to the optical axis so as to correct movement of an image during camera shake.

Accordingly, the zoom lens can be downsized when compared to a type of zoom lens comprising an optical system for correcting camera shake attached in front of the lens. Furthermore, since the entire group having a united optical performance is decentered, deterioration in the aberration can be decreased when compared to a zoom lens in which only a part in the groups are moved.

In the first zoom lens mentioned above, preferably the third group is composed of one lens. Accordingly, a load on the driving system will be decreased when correcting camera shake, and power consumption can be saved.

Preferably the third lens group is composed of two lenses: a positive

lens and a negative lens. Accordingly, the aberration when correcting camera shake can be corrected more efficiently, and deterioration of image quality can be decreased even when correcting camera shake.

Preferably the third lens group is composed of three lenses comprising at least one positive lens and at least one negative lens. The third lens group is required to have a strong positive power to decrease the full length in order to obtain a small zoom lens. In this preferable embodiment, aberration occurring at this time can be corrected with the three lenses.

It is also preferable that the third lens group includes a positive lens, and a cemented lens of a positive lens and a negative lens. Accordingly, tolerance when assembling a group of correcting lenses can be eased.

Preferably the third lens group is composed of at least one aspherical surface. Accordingly, aberration when correcting camera shake can be corrected with further efficiency, and thus, performance when moving the lenses can be improved.

Preferably the fourth lens group comprises at least one aspherical surface. Accordingly, aberration when correcting camera shake can be corrected as well as when a stationary state with further efficiency.

Preferably, the shifting amount Y of the third lens group at a focal length f of an entire system when correcting camera shake, the shifting amount Yt of the third lens group at a telephoto end, and the focal length ft of the telephoto end satisfy the following conditional expressions.

$Yt>Y$; and

$(Y/Yt) / (f/ft)<1.5$

Accordingly, deterioration in the optical performance can be prevented when camera shake occurs.

Preferably, a focal length f3 of the third lens group and a focal length fw of an entire system at a wide-angle end satisfy the following conditional expression.

$2.0 < f3/fw < 4.0$

Accordingly, the shifting amount when correcting camera shake can be decreased and the zoom lens can be shortened as a whole, and thus, a small zoom lens can be provided.

Preferably, a surface on the object side of a lens disposed closest to the object side in the third lens group is aspherical, and a local radius of curvature R10 in the vicinity of an optical axis and a local radius of curvature R11 in an outer peripheral portion satisfy the following conditional expression.

$$1.05 < R11/R10 < 2.5$$

Accordingly, spherical aberration can be corrected satisfactorily.

Preferably, a surface on the object side of a lens disposed closest to the object side in the fourth lens group is aspherical, and a local radius of curvature R20 in the vicinity of an optical axis and a local radius of curvature R21 in an outer peripheral portion satisfy the following conditional expression.

$$1.05 < R21/R20 < 2.0$$

Accordingly, coma-aberration on the upper flux of the off-axis ray can be corrected favorably.

Next, a first video camera of the present invention is characterized in that it includes the above-mentioned first zoom lens. Accordingly, the video camera has a function to correct camera shake and can be downsized and weight-reduced.

Next, a second zoom lens of the present invention comprises a first lens group having a positive refracting power and being fixed with respect to an image plane; a second lens group having a negative refracting power and varying power by moving along an optical axis; a third lens group fixed with respect to the image plane; a fourth lens group fixed with respect to the image plane; and a fifth lens group having a positive refracting power and moving along an optical axis so as to keep the image plane varied by a shift of the second lens group and an object at a predetermined position from a reference surface. In this zoom lens, the first to the fifth lens groups are disposed from the object side in this order. The third lens group and the fourth lens group compose a combination of a lens group having a positive refracting power and a lens group having a negative refracting power, and either the third or fourth lens group is moved vertically with respect to the optical axis so as to correct movement of the image during camera shake.

In such a zoom lens, camera shake is corrected by moving lenses with smaller diameter. Therefore, this type of zoom lens is favorable in downsizing when compared to a zoom lens comprising an optical system for correcting camera shake attached in front of the lens. Moreover, since the aberration performance for each lens group can be adjusted, the aberration performance will deteriorate less when correcting camera shake.

In the second zoom lens, preferably either the third or fourth lens group that is moved is vertically with respect to the optical axis so as to correct movement of the image during camera shake is composed of two

lenses: one positive lens and one negative lens.

It is also preferable that the third lens group has a positive refracting power and the fourth lens group has a negative refracting power, and the third lens group is moved vertically with respect to the optical axis so as to correct movement of the image during camera shake. In such a zoom lens, long back focus can be secured easily since the fourth lens group includes lenses having a negative refracting power. This is suitable for an optical system of a video camera using three imaging devices, which requires a long back focus.

Preferably, the fourth lens group is composed of two lenses separated from each other: one positive lens and one negative lens.

Preferably, the fourth lens group is composed of two cemented lenses: one positive lens and one negative lens.

Preferably, the third lens group has a negative refracting power and the fourth lens group has a positive refracting power, and the fourth lens group is moved vertically with respect to the optical axis so as to correct movement of the image during camera shake. Since the fourth lens group includes lenses having a positive refracting power in such a zoom lens, light entering the fifth lens group can be lowered and the lens diameter also can be reduced. Therefore, a load on a focusing actuator can be lighter.

Preferably, the third lens group and the fourth lens group are composed two lenses respectively, and Abbe's number $\nu31$ of one lens of the third group, Abbe's number $\nu32$ of the remaining lens of the third group, Abbe's number $\nu41$ of one lens of the fourth group and Abbe's number $\nu42$ of the remaining lens of the fourth group satisfy the following conditional expressions.

$$|\nu31-\nu32|>25$$

$$|\nu41-\nu42|>25$$

Since such a zoom lens can provide a sufficient achromatic effect, deterioration in magnification chromatic aberration can be decreased even when shifting the lenses.

Preferably, either the third or fourth lens group that is moved vertically with respect to the optical axis in order to correct movement of an image during camera shake is composed of two lenses: one lens having a positive refracting power and one lens having a negative refracting power being disposed separately from the object side in this order, and the lenses have sag amounts equal on the object side and on the image side.

Preferably, either the third or fourth lens group that group is moved vertically with respect to the optical axis in order to correct movement of an image during camera shake is composed of three lenses comprising at least one positive lens and at least one negative lens. In a small zoom lens, the third lens group is required to have a strong positive power to decrease the whole length. Aberrations occurring at this time can be corrected by using three lenses in this embodiment.

Preferably, either the third or fourth lens group that is moved vertically with respect to the optical axis in order to correct movement of an image during camera shake is composed of one lens. Accordingly, a load on the driving system will be lighter when correcting camera shake and power consumption can be decreased.

Preferably, either the third or fourth lens group that is moved vertically with respect to the optical axis in order to correct movement of an image during camera shake comprises at least one aspherical surface. Such a zoom lens can have improved performance during lens shifting.

Preferably, either the third or fourth lens group that is moved vertically with respect to the optical axis in order to correct movement of an image during camera shake comprises a convex lens having an aspherical surface when viewed from the object side, and a local radius of curvature rS1 for a diameter occupying 10% of lens effective diameter and a local radius of curvature rS9 for a diameter occupying 90% of lens effective diameter satisfy the following conditional expression.

$$0.01<rS1/rS9<2.00$$

Such a zoom lens can provide sufficient aberration performance.

Preferably, a focal length f3 of the third lens group and a focal length f34 of a composite focal length of the third and fourth lens groups satisfy the following conditional expression.

$$0.40<|f3/f34|<0.85$$

Since such a zoom lens can control the power of the correcting lenses, deterioration in the aberration performance can be prevented and moreover, degree of lens movement when correcting camera shake can be controlled. Therefore, the lens can be made smaller, and this is favorable for downsizing.

Preferably, a focal length fw of an entire system at the wide-angle end and a distance BF between the final surface of the lens and the image plane in the air satisfy the following conditional expression.

$$2.0<BF<fw<5.0$$

Accordingly, a zoom lens with a long back focus can be provided.

Preferably, a focal length fw of an entire system at the wide-angle end, focal length fi (i=1-5) of the i-th lens group, and a composite focal length f34 of the third and fourth lens groups satisfy the following expressions.

$5.0<f1/fw<8.0$

$0.5<|f2|/fw<1.6$

$4.0<f34/fw<9.5$

$2.0<f5/fw<5.0$

Accordingly, a small zoom lens can be provided.

It is also preferable that the shifting amount Y of the third lens group at a focal length f of an entire system when correcting camera shake, the shifting amount Yt of the third lens group at a telephoto end and a focal length ft of the telephoto end satisfy the following conditional expressions.

$Yt>Y$; and

$(Y/Yt) / (f/ft)<1.5$

Accordingly, overcorrection and also deterioration in the optical performance can be prevented.

Next, a second video camera of the present invention is characterized in that it comprises the second zoom lens. Accordingly, a small video camera with high-performance and a function to correct camera shake is obtainable.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view showing the arrangement of a zoom lens in a first embodiment according to the present invention.

FIG. 2 illustrates various aberrations at a wide-angle end in the first embodiment according to the present invention.

FIG. 3 illustrates various aberrations at a standard position in the first embodiment according to the present invention.

FIG. 4 illustrates various aberrations at a telephoto end in the first embodiment according to the present invention.

FIG. 5 is a view showing the arrangement of a zoom lens in a second embodiment according to the present invention.

FIG. 6 illustrates various aberrations at a wide-angle end in the second embodiment according to the present invention.

FIG. 7 illustrates various aberrations at a standard position in the second embodiment according to the present invention.

FIG. 8 illustrates various aberrations at a telephoto end in the second

embodiment according to the present invention.

FIG. 9 is a view showing the arrangement of a zoom lens in a third embodiment according to the present invention.

FIG. 10 illustrates various aberrations at a wide-angle end in the third embodiment according to the present invention.

FIG. 11 illustrates various aberrations at a standard position in the third embodiment according to the present invention.

FIG. 12 illustrates various aberrations at a telephoto end in the third embodiment according to the present invention.

FIG. 13 is a view showing the arrangement of a zoom lens in a fourth embodiment according to the present invention.

FIG. 14 illustrates various aberrations at a wide-angle end in the fourth embodiment according to the present invention.

FIG. 15 illustrates various aberrations at a standard position in the fourth embodiment according to the present invention.

FIG. 16 illustrates various aberrations at a telephoto end in the fourth embodiment according to the present invention.

FIG. 17 is a view showing the arrangement of a zoom lens in a fifth embodiment according to the present invention.

FIG. 18 illustrates various aberrations at a wide-angle end in the fifth embodiment according to the present invention.

FIG. 19 illustrates various aberrations at a standard position in the fifth embodiment according to the present invention.

FIG. 20 illustrates various aberrations at a telephoto end in the fifth embodiment according to the present invention.

FIG. 21 illustrates various aberrations at a wide-angle end of a second example in the fifth embodiment according to the present invention.

FIG. 22 illustrates various aberrations at a standard position of the second example in the fifth embodiment according to the present invention.

FIG. 23 illustrates various aberrations at a telephoto end of the second example in the fifth embodiment according to the present invention.

FIG. 24 is a view showing the arrangement of a zoom lens in a sixth embodiment according to the present invention.

FIG. 25 illustrates various aberrations at a wide-angle end in the sixth embodiment according to the present invention.

FIG. 26 illustrates various aberrations at a standard position in the sixth embodiment according to the present invention.

FIG. 27 illustrates various aberrations at a telephoto end in the sixth embodiment according to the present invention.

FIG. 28 illustrates various aberrations at a telephoto end in the sixth embodiment according to the present invention at a correction of 0.5 degrees.

FIG. 29 is a view showing the arrangement of a zoom lens in a seventh embodiment according to the present invention.

FIG. 30 illustrates various aberrations at a wide-angle end in the seventh embodiment according to the present invention.

FIG. 31 illustrates various aberrations at a standard position in the seventh embodiment according to the present invention.

FIG. 32 illustrates various aberrations at a telephoto end in the seventh embodiment according to the present invention.

FIG. 33 illustrates various aberrations at a telephoto end in the seventh embodiment according to the present invention at a correction of 0.5 degrees.

FIG. 34 is a view showing the arrangement of a zoom lens in a eighth embodiment according to the present invention.

FIG. 35 illustrates various aberrations at a wide-angle end in the eighth embodiment according to the present invention.

FIG. 36 illustrates various aberrations at a standard position in the eighth embodiment according to the present invention.

FIG. 37 illustrates various aberrations at a telephoto end in the eighth embodiment according to the present invention.

FIG. 38 illustrates various aberrations at a telephoto end in the seventh embodiment according to the present invention at a correction of 0.5 degrees.

FIG. 39 is a view showing the arrangement of a zoom lens in a ninth embodiment according to the present invention.

FIG. 40 illustrates various aberrations at a wide-angle end in the ninth embodiment according to the present invention.

FIG. 41 illustrates various aberrations at a standard position in the ninth embodiment according to the present invention.

FIG. 42 illustrates various aberrations at a telephoto end in the ninth embodiment according to the present invention.

FIG. 43 illustrates various aberrations at a telephoto end in the ninth embodiment according to the present invention at a correction of 0.5 degrees.

FIG. 44 is a view showing the arrangement of a video camera in a

tenth embodiment according to the present invention.

FIG. 45 is a view showing the arrangement of a zoom lens in an eleventh embodiment according to the present invention.

FIG. 46 is a view specifically showing the arrangement of the zoom lens in the eleventh embodiment according to the present invention.

FIG. 47 illustrates various aberrations at a wide-angle end in the eleventh embodiment according to the present invention.

FIG. 48 illustrates various aberrations at a standard position in the eleventh embodiment according to the present invention.

FIG. 49 illustrates various aberrations at a telephoto end in the eleventh embodiment according to the present invention.

FIG. 50 illustrates various aberrations at a wide-angle end of a second example in the eleventh embodiment according to the present invention.

FIG. 51 illustrates various aberrations at a standard position of the second example in the eleventh embodiment according to the present invention.

FIG. 52 illustrates various aberrations at a telephoto end of the second example in the eleventh embodiment according to the present invention.

FIG. 53 illustrates various aberrations at a wide-angle end of a third example in the eleventh embodiment according to the present invention.

FIG. 54 illustrates various aberrations at a standard position of the third example in the eleventh embodiment according to the present invention.

FIG. 55 illustrates various aberrations at a telephoto end of the third example in the eleventh embodiment according to the present invention.

FIG. 56 is a view showing the arrangement of a zoom lens in a twelfth embodiment according to the present invention.

FIG. 57 is a view specifically showing the arrangement of the zoom lens in the twelfth embodiment.

FIG. 58 illustrates various aberrations at a wide-angle end in the twelfth embodiment according to the present invention.

FIG. 59 illustrates various aberrations at a standard position in the twelfth embodiment according to the present invention.

FIG. 60 illustrates various aberrations at a telephoto end in the twelfth embodiment according to the present invention.

FIG. 61 is a view showing the arrangement of a zoom lens in a thirteenth embodiment according to the present invention.

FIG. 62 illustrates various aberrations at a wide-angle end in the

thirteenth embodiment according to the present invention.

FIG. 63 illustrates various aberrations at a standard position in the thirteenth embodiment according to the present invention.

FIG. 64 illustrates various aberrations at a telephoto end in the thirteenth embodiment according to the present invention.

FIG. 65 is a view showing the arrangement of a video camera in a fourteenth embodiment according to the present invention.

FIG. 66 is a view showing the arrangement of a zoom lens in a fifteenth embodiment according to the present invention.

FIG. 67 illustrates various aberrations at a wide-angle end in the fifteenth embodiment according to the present invention.

FIG. 68 is illustrates various aberrations at a standard position in the fifteenth embodiment according to the present invention.

FIG. 69 illustrates various aberrations at a telephoto end in the fifteenth embodiment according to the present invention.

FIG. 70 is a view showing the arrangement of a zoom lens in a sixteenth embodiment according to the present invention.

FIG. 71 illustrates various aberrations at a wide-angle end in the sixteenth embodiment according to the present invention.

FIG. 72 illustrates various aberrations at a standard position in the sixteenth embodiment according to the present invention.

FIG. 73 illustrates various aberrations at a telephoto end in the sixteenth embodiment according to the present invention.

FIG. 74 is a view showing the arrangement of a zoom lens in a seventeenth embodiment according to the present invention.

FIG. 75 illustrates various aberrations at a wide-angle end in the seventeenth embodiment according to the present invention.

FIG. 76 illustrates various aberrations at a standard position in the seventeenth embodiment according to the present invention.

FIG. 77 illustrates various aberrations at a telephoto end in the seventeenth embodiment according to the present invention.

FIG. 78 is a view showing the arrangement of a zoom lens in a eighteenth embodiment according to the present invention.

FIG. 79 illustrates various aberrations at a wide-angle end in the eighteenth embodiment according to the present invention.

FIG. 80 illustrates various aberrations at a standard position in the eighteenth embodiment according to the present invention.

FIG. 81 illustrates various aberrations at a telephoto end in the eighteenth embodiment according to the present invention.

FIG. 82 is a view showing the arrangement of a zoom lens in a nineteenth embodiment according to the present invention.

FIG. 83 illustrates various aberrations at a wide-angle end in the nineteenth embodiment according to the present invention.

FIG. 84 illustrates various aberrations at a standard position in the nineteenth embodiment according to the present invention.

FIG. 85 illustrates various aberrations at a telephoto end in the nineteenth embodiment according to the present invention.

FIG. 86 is a view showing the arrangement of a zoom lens in a twentieth embodiment according to the present invention.

FIG. 87 illustrates various aberrations at a wide-angle end in the twentieth embodiment according to the present invention.

FIG. 88 illustrates various aberrations at a standard position in the twentieth embodiment according to the present invention.

FIG. 89 illustrates various aberrations at a telephoto end in the twentieth embodiment according to the present invention.

FIG. 90 is a view showing the arrangement of a zoom lens in a twenty-first embodiment according to the present invention.

FIG. 91 illustrates various aberrations at a wide-angle end in the twenty-first embodiment according to the present invention.

FIG. 92 illustrates various aberrations at a standard position in the twenty-first embodiment according to the present invention.

FIG. 93 illustrates various aberrations at a telephoto end in the twenty-first embodiment according to the present invention.

FIG. 94 is a view showing the arrangement of a video camera in a twenty-second embodiment according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, the present invention will be described by way of illustrative embodiments.

(First Embodiment)

FIG. 1 is a view showing the arrangement of a zoom lens in a first embodiment according to the present invention. As shown in FIG. 1, a zoom lens has a structure in which a first lens group 11, a second lens group 12, a third lens group 13, and a fourth lens group 14 are disposed from an object

side (left side in FIG. 1) to an image plane side (right side in FIG. 1) in this order.

The first lens group 11 has a positive refracting power, and is fixed with respect to the image plane in varying power and focusing. The second lens group 12 has a negative refracting power and varies power by moving along an optical axis. The third lens group 13 is composed of a single lens having a positive refracting power and is fixed with respect to the image plane in varying power and focusing.

When camera shake occurs, shake of an image is corrected by moving the third lens group 13 in a direction vertical to the optical axis. Since camera shake is corrected in this way by moving a lens with smaller diameter, a small and lightweight video camera can be provided. Furthermore, power consumption also can be reduced since a load on the driving system becomes lighter.

The fourth lens group 14 has a positive refracting power, moves along an optical axis so as to keep the image plane varied by the shift of the second lens group 12 and the object at a predetermined position from a reference surface, thereby moving an image and adjusting the focus thereof at the same time in accordance with variable power. Since aberration of camera shake can be corrected more efficiently by providing at least one aspherical surface to the lens of the third group 13, performance in shifting the lenses can be improved.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 1. In Table 1, r is a radius of curvature of a lens (mm), d is a thickness of a lens or air distance (mm) between lenses, n is a refractive index of each lens with respect to a d-line, and ν is an Abbe's number of each lens with respect to the d-line. These also apply to Tables 4, 7, 10, 13, 19, 25, 31, 37, 43, 46, 49, 52, 55, 58, 61, 64, 67, 70, 73, and 76.

Table 1

Group	Surface	r	d	n	ν
1	1	59.253	1.20	1.80518	25.4
	2	25.011	7.30	1.60311	60.7
	3	−142.977	0.20		
	4	21.743	3.95	1.69680	55.6
	5	60.993	Variable		
2	6	58.338	0.70	1.78500	43.7
	7	6.000	3.39		
	8	−8.642	0.80	1.66547	55.2
	9	8.000	2.60	1.80518	25.5
	10	−85.700	Variable		
3	11	13.702	3.00	1.51450	63.1
	12	−43.933	Variable		
4	13	137.583	0.80	1.84666	23.9
	14	10.422	2.80	1.60602	57.4
	15	−46.478	0.16		
	16	13.885	2.60	1.56883	56.0
	17	−24.865	Variable		
6	18	∞	4.00	1.51633	64.1
	19	∞	—		

Table 2 shows aspherical coefficients in the examples of Table 1. In Table 2, K is a conic constant, and D, E, F, G are aspherical coefficients. These also apply to Tables 5, 8, 11, 14, 26, 32, 38, 44, 47, 50, 53, 56, 59, 62, 65, 68, 71, 74, and 77.

Table 2

Surface	8	11	12	17
K	2.44209×10^{-1}	-2.94965×10^{-2}	-7.06772×10	5.00685
D	9.09600×10^{-5}	-8.84486×10^{-5}	-8.47419×10^{-5}	8.59675×10^{-5}
E	3.54726×10^{-6}	-2.01845×10^{-7}	1.51914×10^{-6}	3.78258×10^{-7}
F	-6.27173×10^{-7}	1.11591×10^{-8}	-3.20919×10^{-8}	4.82992×10^{-10}
G	1.82732×10^{-8}	-1.53242×10^{-10}	-1.00434×10^{-9}	1.52605×10^{-10}

The following Table 3 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens. The standard position is where the third lens group 13 is placed most closely to the fourth lens group 14. In Table 3, f(mm), F/NO, and ω (°) represent a focal length, an F number, and an incident half-angle of view at a wide-angle end, a standard position, and a telephoto end of the zoom lens. These also apply to Tables 6, 9, 12, 15, 26, 45, 48, 51, 54, 57, 60, 63, 66, 69, 72, 75, and 78.

Table 3

	Wide-angle end	Standard position	Telephoto end
f	4.018	23.629	64.517
F/NO	1.462	1.750	2.145
2ω	65.578	11.544	4.354
d5	0.500	16.120	20.600
d10	22.043	5.523	1.943
d14	9.733	5.467	9.131
d19	1.009	5.275	1.611

FIGs. 2 to 4 show various aberrations at the wide-angle end (FIG. 2), the standard position (FIG. 3), and the telephoto end (FIG. 4) of the zoom lens shown in Table 1. In each figure, (a) shows a spherical aberration, where a solid line represents values with respect to the d-line and a broken line represents sine condition; (b) shows astigmatism, where a solid line represents a curvature of a sagittal image plane, and a broken line represents a curvature of a meridional image plane; (c) shows a distortion aberration; (d) shows a longitudinal chromatic aberration, where a solid line represents values with respect to the d-line, a short broken line represents values with respect to an F-line, and a long broken line represents values with respect to a C-line; and (e) shows a chromatic aberration of magnification, where a short broken line represents values with respect to the F-line, and a long broken line represents values with respect to the C-line. This also applies to FIGs. 6 to 8, FIGs. 10 to 12, FIGs. 14 to 16, FIGs. 18 to 20, FIGs. 21 to 23, FIGs. 25 to 27, FIGs. 30 to 32, FIGs. 35 to 37, FIGs. 40 to 42, FIGs. 47 to 49, FIGs. 53 to

55, FIGs. 58 to 60, FIGs. 62 to 64, FIGs. 67 to 69, FIGs. 71 to 73, FIGs. 75 to 77, FIGs.79 to 81, FIGs. 84 to 86, FIGs.87 to 89, and FIGs. 91 to 93.

As is understood from FIGs. 2 to 4, the zoom lens in the present example exhibits satisfactory aberration performance.

The following expressions (1) and (2) relate to the shifting amount of the correcting lens (the third lens group 13).

$$Yt>Y \quad \ldots (1)$$

$$(Y/Yt) / (f/ft)<1.5 \quad \ldots (2)$$

In the expressions (1) and (2), Y represents the shifting amount of the correcting lens (the third lens group 13) at the focal length f of the entire system when correcting camera shake; Yt represents the shifting amount of the correcting lens (the third lens group 13) at the telephoto end; and ft represents a focal length at the telephoto end.

For a zoom lens, a correcting lens moves further as the zoom ratio is great when the correction angle is constant in the whole zooming region. On the other hand, the correcting lens moves less when the zooming ratio is small. That is, when the shift of the lens exceeds the upper limit defined in the expressions (1) and (2), overcorrection occurs and the optical performance will deteriorate greatly. In conclusion, by satisfying the expressions (1) and (2), a zoom lens having a function to correct camera shake, where the aberration performance deteriorate less even during camera shake, can be obtained. This applies also to the following embodiments.

The aspherical shape of the third lens group 13 is defined by the following equation (A), which applies also to the following embodiments 2-5.

$$SAG = \frac{H^2/R}{1+\sqrt{1-(1+K)(H/R)^2}} + D\cdot H^4 + E\cdot H^6 + F\cdot H^8 + G\cdot H^{10} \qquad \text{(A)}$$

SAG: a distance from the apex on the aspherical surface to a point on the same aspherical surface having a height H from the optical axis

H: a height from an optical axis

R is a radius of curvature at the apex on the aspherical surface

K: a conical constant

D, E, F, G: aspherical coefficients

(Second Embodiment)

FIG. 5 is a view showing the arrangement of a zoom lens in a second embodiment according to the present invention. As shown in FIG. 5, a zoom lens has a structure in which a first lens group 51, a second lens group 52, a

third lens group 53, and a fourth lens group 54 are disposed from an object side (left side in FIG. 5) to an image plane side (right side in FIG. 5) in this order. Basic structure and operations are the same as the first embodiment. Specific examples of zoom lenses according to this embodiment are shown in the following Table 4.

Table 4

Group	Surface	r	d	n	ν
1	1	41.544	0.90	1.80518	25.4
	2	21.097	5.00	1.58913	61.2
	3	−95.428	0.20		
	4	17.473	2.70	1.60311	60.7
	5	42.181	Variable		
2	6	41.372	0.65	1.77250	49.6
	7	5.857	2.89		
	8	−7.776	0.85	1.66547	55.2
	9	8.195	2.05	1.84666	23.9
	10	340.000	Variable		
3	11	17.024	2.00	1.68619	34.2
	12	−400.000	Variable		
4	13	−27.898	0.65	1.84666	23.9
	14	18.114	2.35	1.51450	63.1
	15	−18.114	0.10		
	16	18.601	3.40	1.51450	63.1
	17	−9.892	Variable		
5	18	∞	14.00	1.58913	61.0
6	19	∞	3.90	1.51633	64.1
	20	∞	−		

Table 5 shows aspherical coefficients in the examples of Table 4.

Table 5

Surface	8	11	12	15
K	-1.10251×10^{-1}	8.93500×10^{-2}	0.00000	-3.79663×10^{-1}
D	-7.40852×10^{-5}	-8.17245×10^{-5}	1.30862×10^{-5}	2.87398×10^{-4}
E	2.84234×10^{-5}	-4.29821×10^{-6}	-4.69807×10^{-6}	2.61848×10^{-6}
F	-4.64719×10^{-6}	3.44381×10^{-7}	2.94604×10^{-7}	1.24341×10^{-7}
G	2.04967×10^{-7}	-1.18101×10^{-8}	-9.69640×10^{-9}	-1.73992×10^{-9}

The following Table 6 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens.

Table 6

	Wide-angle end	Standard position	Telephoto end
f	4.165	24.690	49.101
F/NO	1.674	2.070	2.373
2ω	59.818	10.314	5.244
d5	0.700	13.501	16.690
d10	18.493	5.692	2.503
d14	5.806	1.925	4.680
d19	1.009	4.890	2.135

FIGs. 6 to 8 show various aberrations at the wide-angle end (FIG. 6), the standard position (FIG. 7), and the telephoto end (FIG. 8) of the zoom lens shown in Table 4. As is understood from FIGs. 6 to 8, the zoom lens in the present example exhibits satisfactory aberration performance.

By satisfying the expressions (1) and (2), a zoom lens having a function to correct camera shake can be obtained, and the aberration performance deteriorate less during camera shake.

(Third Embodiment)

FIG. 9 is a view showing the arrangement of a zoom lens in a third

embodiment according to the present invention. As shown in FIG. 9, a zoom lens has a structure in which a first lens group 91, a second lens group 92, a third lens group 93, and a fourth lens group 94 are disposed from an object side (left side in FIG. 9) to an image plane side (right side in FIG. 9) in this order. The first lens group 91 has a positive refracting power and is fixed with respect to the image plane in varying power and focusing.

The second lens group 92 has a negative refracting power and varies power by moving along the optical axis. The third lens group 93 is composed of two lenses: one lens having a positive refracting power and one lens having a negative refracting power, and it is fixed with respect to the image plane in varying power and focusing. When camera shake occurs, shake of an image is corrected by moving the whole third lens group 93 in a direction vertical to the optical axis.

As mentioned above, by increasing the number of movable lenses, high optical performance can be maintained when the lenses are moved. Since a whole lens group of a united optical performance is decentered, deterioration in aberration can be decreased when compared to a type of zoom lens where a part of lenses in a group is moved.

The fourth lens group 94 has a positive refracting power, and it moves along an optical axis so as to keep the image plane varied by a shift of the second lens group 92 and an object at a predetermined position from a reference surface, thereby moving an image and adjusting the focus thereof at the same time in accordance with variable power.

Since the aberration can be corrected during camera shake with greater efficiency by applying at least one aspherical surface to the lenses of the third group 93, performance during the move of the lenses can be improved.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 7.

Table 7

Group	Surface	r	d	n	ν
1	1	48.903	1.00	1.80518	25.4
	2	24.784	4.90	1.60311	60.7
	3	−350.000	0.15		
	4	24.144	2.95	1.60311	60.7
	5	75.644	Variable		
2	6	75.644	0.70	1.78500	43.7
	7	5.533	3.01		
	8	−10.312	0.80	1.60602	57.4
	9	7.244	2.40	1.80518	25.5
	10	∞	Variable		
3	11	−18.171	4.85	1.60602	57.4
	12	−48.748	1.14		
	13	90.000	0.70	1.80518	25.5
	14	9.619	Variable		
4	15	10.214	0.80	1.68649	30.9
	16	6.166	3.30	1.60602	57.4
	17	−48.748	Variable		
5	18	∞	4.00	1.51633	64.1
	19	∞	—		

Table 8 shows aspherical coefficients in the examples of Table 7.

Table 8

Surface	8	11	12	17
K	-9.51113×10^{-0}	-2.86316×10^{-1}	1.70330	-7.38735×10
D	-1.04559×10^{-3}	-1.26750×10^{-4}	2.15292×10^{-4}	7.16504×10^{-5}
E	3.48656×10^{-5}	8.27077×10^{-7}	1.70305×10^{-6}	-1.43472×10^{-6}
F	-1.05636×10^{-6}	-2.35936×10^{-9}	-1.90326×10^{-8}	1.10094×10^{-7}
G	0.00000	0.00000	0.00000	0.00000

The following Table 9 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens.

Table 9

	Wide-angle end	Standard position	Telephoto end
f	3. 952	24. 191	49. 099
F/NO	1. 681	2. 347	3. 079
2ω	62. 775	6. 669	3. 287
d5	0. 700	20. 905	25. 630
d10	26. 926	6. 721	1. 996
d14	9. 468	2. 408	7. 389
d19	2. 008	9. 069	4. 088

FIGs. 10 to 12 show various aberrations at the wide-angle end (FIG. 10), the standard position (FIG. 11), and the telephoto end (FIG. 12) of the zoom lens shown in Table 7. As is understood from FIGs. 10 to 12, the zoom lens in the present example exhibits satisfactory aberration performance.

By satisfying the expressions (1) and (2), a zoom lens having a function to correct camera shake can be obtained, and the aberration performance deteriorates less during camera shake.

(Fourth Embodiment)

FIG. 13 is a view showing the arrangement of a zoom lens in a fourth embodiment according to the present invention. As shown in FIG. 13, a zoom lens has a structure in which a first lens group 131, a second lens group 132, a third lens group 133, and a fourth lens group 134 are disposed from an object side (left side in FIG. 13) to an image plane side (right side in FIG. 13) in this order.

The first lens group 131 has a positive refracting power and is fixed with respect to the image plane even in varying power and focusing. The second lens group 132 has a negative refracting power and varies power by moving along the optical axis. The third lens group 133 is composed of two lenses: one lens having a positive refracting power and one lens having a negative refracting power, and it is fixed with respect to the image plane in

varying power and focusing.

When camera shake occurs, shake of the image is corrected by moving the whole third lens group 133 in a direction vertical to the optical axis. As mentioned above, by increasing the number of movable lenses, high optical performance can be maintained when the lenses are moved.

Since the third lens group 133 in this embodiment is composed of two lenses: one lens having a positive refracting power and one lens having a negative refracting power, aberration can be corrected more efficiently when correcting camera shake, and deterioration in the image quality can be decreased when correcting camera shake.

The fourth lens group 134 has a positive refracting power, moves along an optical axis so as to keep the image plane varied by a shift of the second lens group 132 and an object at a predetermined position from a reference surface, thereby moving an image and adjusting the focus thereof at the same time in accordance with variable power. Since the aberration can be corrected when correcting camera shake further efficiently by applying at least one aspherical surface to the lenses of the third group 133, performance can be improved when the lenses are moved.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 10.

Table 10

Group	Surface	r	d	n	ν
1	1	41.544	0.90	1.80518	25.4
	2	21.097	5.00	1.58913	61.2
	3	−95.428	0.20		
	4	17.473	2.70	1.60311	60.7
	5	42.181	Variable		
2	6	41.372	0.65	1.77250	49.6
	7	5.857	2.89		
	8	−7.776	0.85	1.66547	55.2
	9	8.195	2.05	1.84666	23.9
	10	340.000	Variable		
3	11	14.743	2.45	1.51450	63.1
	12	−45.960	1.50		
	13	33.378	1.50	1.66547	55.2
	14	19.936	Variable		
4	15	−41.230	0.65	1.84666	23.9
	16	22.061	2.20	1.51450	63.1
	17	−38.993	0.10		
	18	14.246	3.40	1.51450	63.1
	19	−9.338	Variable		
5	20	∞	14.00	1.58913	61.0
6	22	∞	3.90	1.51633	64.1
	23	∞	—		

Table 11 shows aspherical coefficients in the Examples of Table 10.

Table 11

Surface	8	11	12	17
K	-1.10251×10^{-1}	0.00000	0.00000	-3.79663×10^{-1}
D	-7.40852×10^{-5}	-1.56773×10^{-5}	9.91198×10^{-5}	4.04267×10^{-4}
E	2.84234×10^{-5}	2.64330×10^{-6}	4.19737×10^{-6}	3.44573×10^{-6}
F	-4.64719×10^{-6}	-2.20686×10^{-7}	2.48747×10^{-8}	1.86356×10^{-7}
G	2.04967×10^{-7}	5.27090×10^{-10}	1.70900×10^{-9}	-2.73441×10^{-9}

The following Table 12 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens.

Table 12

	Wide-angle end	Standard position	Telephoto end
f	4.129	24.191	49.099
F/NO	1.681	2.070	2.334
2ω	60.356	10.536	5.287
d5	0.700	13.501	16.690
d10	16.993	4.192	1.003
d14	5.806	1.925	4.680
d19	1.009	4.890	2.135

FIGs. 14 to 16 show various aberrations at the wide-angle end (FIG. 14), the standard position (FIG. 15), and the telephoto end (FIG. 16) of the zoom lens shown in Table 10. As is shown in FIGs. 14 to 16, the zoom lens in the present embodiment exhibits satisfactory aberration performance.

By satisfying the expressions (1) and (2), a zoom lens having a function to correct camera shake can be obtained, in which the aberration performance deteriorates less during camera shake.

(Fifth Embodiment)

FIG. 17 is a view showing the arrangement of a zoom lens in a fifth embodiment according to the present invention. As shown in FIG. 17, a zoom

lens has a structure in which a first lens group 171, a second lens group 172, a third lens group 173, and a fourth lens group 174 are disposed from an object side (left side in FIG. 17) to an image plane side (right side in FIG. 17) in this order.

The first lens group 171 has a positive refracting power and is fixed with respect to the image plane even in varying power and focusing. The second lens group 172 has a negative refracting power and varies power by moving along the optical axis.

The third lens group 173 is composed of three lenses including at least one lens having a positive refracting power and at least one lens having a negative refracting power, and the group is fixed with respect to the image plane in varying power and focusing.

When camera shake occurs, shake of the image is corrected by moving the whole third lens group 173 in a direction vertical to the optical axis. For a small zoom lens, the third lens group 173 is required to have a strong positive refracting power to shorten the whole length, and this will cause aberration.

However, since the zoom lens in this embodiment has a third lens group 173 composed of three lenses, aberration occurring at the third lens group 173 is suppressed and high optical performance is maintained when the lenses are moved.

The fourth lens group 174 has a positive refracting power, and moves along an optical axis so as to keep the image plane varied by a shift of the second lens group 172 and an object at a predetermined position from a reference surface, thereby moving an image and adjusting the focus thereof at the same time in accordance with variable power.

Since the aberration can be corrected during camera shake with more efficiency by applying at least one aspherical surface to the lenses of the third group 173, performance can be improved when the lenses are moved.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 13.

Table 13

Group	Surface	r	d	n	ν
1	1	48.280	0.90	1.80518	25.4
	2	17.748	4.53	1.60311	60.7
	3	−67.680	0.20		
	4	14.615	2.67	1.69680	55.6
	5	42.483	Variable		
2	6	42.483	0.60	1.77250	49.6
	7	4.842	2.15		
	8	−6.478	0.80	1.66547	55.2
	9	5.874	1.80	1.80518	25.5
	10	−323.142	Variable		
3	11	7.889	4.55	1.66547	55.2
	12	−14.939	0.10		
	13	9.748	2.40	1.51633	64.1
	14	−104.180	0.60	1.84666	23.9
	15	5.767	Variable		
4	16	7.481	2.87	1.51450	63.1
	17	−31.976	Variable		
5	18	∞	4.30	1.51633	64.1
	19	∞	—		

Table 14 shows aspherical coefficients in the Examples of Table 13.

Table 14

Surface	8	11	12	16
K	-1.30349	-7.99910	-6.269020	-1.99544×10^{-2}
D	-6.01825×10^{-4}	-1.39502×10^{-4}	-4.75872×10^{-6}	-2.07422×10^{-5}
E	-2.10812×10^{-5}	2.02487×10^{-7}	1.65237×10^{-7}	-6.99987×10^{-6}
F	0.00000	0.00000	0.00000	0.00000
G	0.00000	0.00000	0.00000	0.00000

The following Table 15 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens.

Table 15

	Wide-angle end	Standard position	Telephoto end
f	4.827	21.634	46.275
F/NO	1.461	2.197	2.851
2ω	59.897	12.728	6.609
d5	0.700	9.569	12.450
d10	13.383	4.514	1.633
d14	6.113	1.859	6.193
d19	1.000	5.254	0.920

FIGs. 18 to 20 show various aberrations at the wide-angle end (FIG. 18), the standard position (FIG. 19), and the telephoto end (FIG. 20) of the zoom lens shown in Table 13. As is shown in FIGs. 18 to 20, the zoom lens in the present example exhibits satisfactory aberration performance.

By satisfying the expressions (1) and (2), a zoom lens having a function to correct camera shake can be obtained, and the aberration performance deteriorates less during camera shake.

Specific examples of zoom lenses according to this embodiment, in addition to the above-mentioned lenses, are shown in the following Table 16.

Table 16

Group	Surface	r	d	n	ν
1	1	31.758	0.90	1.80518	25.5
	2	15.951	4.50	1.58913	61.2
	3	−135.286	0.15		
	4	14.102	3.00	1.58913	61.2
	5	45.000	Variable		
2	6	45.000	0.50	1.77250	49.6
	7	4.188	2.36		
	8	−6.630	0.70	1.60602	57.8
	9	5.382	1.75	1.80518	25.5
	10	88.671	Variable		
3	11	6.731	3.50	1.60602	57.8
	12	−11.394	0.50		
	13	12.785	1.70	1.51633	64.1
	14	−350.000	0.50	1.84666	23.9
	15	5.875	Variable		
4	16	7.945	1.95	1.51450	63.1
	17	−28.581	Variable		
5	18	∞	3.70	1.51633	64.1
	19	∞	—		

Table 17 shows aspherical coefficients in the Examples of Table 16.

Table 17

Surface	8	11	12	16
K	-3.79187	-1.49571	-5.54316	-2.04960
D	-1.52553×10^{-3}	6.24513×10^{-5}	9.21711×10^{-6}	3.68450×10^{-4}
E	-4.26600×10^{-6}	-3.45653×10^{-6}	-4.27080×10^{-6}	-8.68455×10^{-6}
F	-1.29623×10^{-6}	1.02115×10^{-7}	1.47247×10^{-7}	-2.70755×10^{-9}

The following Table 18 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens.

Table 18

	Wide-angle end	Standard position	Telephoto end
f	4.355	23.581	48.637
F/NO	1.857	2.101	2.485
2ω	57.157	10.756	5.259
d5 d10 d14 d19	0.500 14.442 7.262 1.011	10.347 4.595 2.386 5.888	12.880 2.062 5.951 2.323

FIGs. 21 to 23 show various aberrations at the wide-angle end (FIG. 21), the standard position (FIG. 22), and the telephoto end (FIG. 23) of the zoom lens shown in Table 16. As is understood from FIGs. 21 to 23, the zoom lens in the present example exhibits satisfactory aberration performance.

By satisfying the expressions (1) and (2), a zoom lens having a function to correct camera shake can be obtained, and the aberration performance deteriorates less during camera shake.

The first to fifth embodiments relate to zoom lenses. By using these zoom lenses, video cameras having a function to correct camera shake can be provided, and such video cameras can be downsized and lightweight.

(Sixth Embodiment)

FIG. 24 is a view showing the arrangement of a zoom lens in a sixth embodiment according to the present invention. As shown in FIG. 24, a zoom lens has a structure in which a first lens group 241, a second lens group 242, a third lens group 243, a fourth lens group 244, and a plate 245 equivalent to an optical low-pass filter and a face plate of a CCD are disposed from an object side to an image plane side in this order.

The first lens group 241 has a positive refracting power, and is fixed with respect to the image plane 246 in varying power and focusing. The second lens group 242 has a negative refracting power as a whole and varies power by moving along an optical axis. The third lens group 243 is composed of three lenses: a positive lens, a positive lens, and a negative lens disposed from the object side in this order, and is fixed with respect to the image plane 246 in varying power and focusing. The fourth lens group 244 is composed of

one positive lens. The fourth lens group 244 moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power.

When camera shake occurs, shake of an image is corrected by moving the third lens group 243 vertically with respect to the optical axis direction. Since the third lens group 243 is smaller in lens diameter than the first lens group 241, correction by moving the third lens group 243 will cause less load for the driving system, and electric power also can be saved. By satisfying the expressions (1) and (2), a zoom lens having a function to correct camera shake, where the aberration performance deteriorates less during camera shake, can be obtained.

The following expression (3) relates to a shift of a third lens group.

$$2.0 < f3 / fw < 4.0 \qquad \ldots (3)$$

In the above expression (3), f3 represents a focal length of the third lens group and fw represents a focal length of the entire system at a wide-angle end.

When the value falls below the lower limit, the aberration will be difficult to correct in a stationary state or when correcting camera shake even if the third lens group is composed of three lenses. When the value exceeds the upper limit, the shifting amount is increased when correcting camera shake and the zoom lens barrel becomes large in diameter. Moreover, the entire length is increased and the zoom lens cannot be downsized. By satisfying the expression (3), the shifting amount when correcting camera shake can be decreased and the whole length of the zoom lens can be shortened, and thus, a small zoom lens can be provided.

Furthermore, by applying at least one aspherical surface to the third lens group as a shift lens group and also to the fourth lens group having focusing action, aberration can be corrected when correcting camera shake as well as in the stationary state.

The following expression (4) relates to an aspherical shape of the object side of a lens of the third lens group, when the lens is disposed closest to the object.

$$1.05 < R11 / R10 < 2.5 \qquad \ldots (4)$$

In the expression (4), R10 represents a local radius of curvature in the vicinity of the optical axis, and R11 represents a local radius of curvature in an outer peripheral portion.

The expression (4) defines a range to correct the spherical aberration

satisfactorily. A negative spherical aberration occurs when the value falls below the lower limit, while positive spherical aberration occurs as a result of overcorrection when the value exceeds the upper limit.

The following expression (5) relates to an aspherical shape of a lens of the fourth lens group when viewed from the object side.

$$1.05<R21<R20<2.0 \quad \ldots (5)$$

R20 represents a local radius of curvature in the vicinity of the optical axis, and R21 represents a local radius of curvature in an outer peripheral portion.

The expression (5) defines a range to satisfactorily correct a coma aberration of an upper flux of an off-axis ray. An internal coma occurs when the value falls below the lower limit, while an external coma occurs when the value exceeds the upper limit.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 19.

Table 19

Group	Surface	r	d	n	v
1	1	31.089	0.90	1.80518	25.4
	2	15.820	4.50	1.58913	61.2
	3	−171.154	0.15		
	4	14.460	3.00	1.60311	60.7
	5	48.740	Variable		
2	6	48.740	0.50	1.77250	49.6
	7	4.206	2.34		
	8	−8.647	0.55	1.60602	57.4
	9	5.292	1.75	1.80518	25.4
	10	88.671	Variable		
3	11	7.268	3.25	1.51450	63.1
	12	−14.052	0.10		
	13	9.072	2.20	1.51895	57.3
	14	−37.099	0.50		
	15	60.905	0.50	1.84666	25.4
	16	5.422	Variable		
4	17	7.232	2.00	1.51450	63.1
	18	−42.485	Variable		
5	19	∞	3.70	1.51633	64.1
	20	∞	−		

The aspherical shape is defined by the following equation (B). (This also applies to examples 2 to 4.)

$$SAG = \frac{H^2/R}{1+\sqrt{1-(1+K)(H/R^2)}} + D \cdot H^4 + E \cdot H^6 + F \cdot H^8 \qquad \text{(B)}$$

SAG: a distance from the apex on the aspherical surface to a point on the same aspherical surface having a height H from the optical axis

H: a height from an optical axis

R: a radius of curvature at the apex on the aspherical surface

K: a conical constant

D, E, F: aspherical coefficients

The following Table 20 shows aspherical shapes of the zoom lens in

the present example.

Table 20

Surface	8	1 1	1 2	1 7
K	-3.46709	-1.57334	-4.56016	-1.39803
D	-1.36790×10^{-3}	-6.68922×10^{-5}	1.39115×10^{-5}	1.90786×10^{-4}
E	-1.82278×10^{-5}	-1.31623×10^{-6}	-1.82005×10^{-6}	9.90799×10^{-6}
F	-5.96614×10^{-7}	8.53637×10^{-8}	1.00886×10^{-7}	-6.93646×10^{-7}

The following Table 21 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens. A standard position represents a position where the third lens group 243 is disposed the closest to the fourth lens group 244. The Table 21 indicates also a shifting amount Y of the third lens group at a correction of 0.5 degrees.

Table 21

	Wide-angle end	Standard position	Telephoto end
f	4.350	23.464	48.623
F/NO	1.873	2.096	2.490
ω	28.770	5.415	2.638
d 5	0.500	10.344	12.893
d 1 0	14.442	4.597	2.049
d 1 6	7.262	2.393	5.880
d 1 8	1.012	5.880	2.393
Y	0.034	0.197	0.392
Expression (2)	0.972	1.041	1.000

As shown in FIG. 21, the a shift of the third lens group in this embodiment satisfies the expressions (1) and (2), and thus, it realizes optical performance with less deterioration when compared to a stationary state.

Furthermore, in the zoom lens of the present example, a focal length

f3 of the third lens group satisfies the expression (3) and a small zoom lens is provided.

Table 22

Fw	f3	Expression (3) (f3/fw)
4.350	11.311	2.60

In this embodiment, the third lens group has a lens at the side closest to the object, and the both surfaces of the lens are aspherical. Especially, the local radius of curvature R10 in the vicinity of the object-side surface and the local radius of curvature R11 in an outer peripheral portion have values shown in the following Table 23, and satisfy the expression (4). As a result, the embodiment realizes excellent aberration performance not only in the stationary state but when correcting camera shake, and especially, the embodiment realizes a spherical aberration that is satisfactorily corrected.

Table 23

R10	R11	Expression (4) (R11/R10)
7.268	13.516	1.86

Furthermore, the lens of the fourth lens group has an aspherical surface when viewed from the object side, a local radius of curvature R20 in the vicinity of an optical axis and a local radius of curvature R11 in an outer peripheral portion with the values shown in Table 24. Moreover, when the expression (5) is satisfied, excellent aberration performance is realized not only in its stationary state but when correcting camera shake. Especially, a satisfactory coma aberration is realized.

Table 24

R20	R21	Expression (5) (R21/R20)
7.232	10.112	1.40

FIGs. 25 to 27 show various aberrations at the wide-angle end, the standard position, and the telephoto end of the zoom lens shown in Table 19.

FIGs. 28 shows aberrations at a telephoto end at a correction of 0.5 degrees. FIGs. 28(a), 28(b) and 28(c) show lateral aberrations at a relative angle of view of 0.75, along the axis, and at a relative angle of view of –0.75. A solid line, the dotted line and the wave line represent values with respect to

the d-line, F-line and C-line (this applies to the following FIGs. 33, 38, and 43). As indicated in FIGs. 25-28, a zoom lens according to this embodiment provides a satisfactory aberration performance.

(Seventh Embodiment)

FIG. 29 is a view showing the arrangement of a zoom lens in a seventh embodiment according to the present invention. As shown in FIG. 29, a zoom lens has a structure in which a first lens group 61, a second lens group 62, a third lens group 63, a fourth lens group 64, and a plate 65 equivalent to an optical low-pass filter and a face plate of a CCD are disposed from an object side to an image plane side in this order.

The first lens group 61 has a positive refracting power, and is fixed with respect to the image plane 66 in varying power and focusing. The second lens group 61 has a negative refracting power and varies power by moving along an optical axis. The third lens group 63 is composed of three lenses: a positive lens, a positive lens, and a negative lens disposed from the object side in this order, and two of the lenses at the image plane side compose a cemented lens of a positive lens and a negative lens. The third lens group 63 is fixed with respect to the image plane 66 in varying power and focusing. The fourth lens group 64 is composed of one positive lens. The fourth lens group 64 moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power.

When camera shake occurs, shake of an image is corrected by moving the third lens group 63 vertically with respect to the optical axis direction. Since the third lens group 63 is smaller in lens diameter than the first lens group 61, correction by moving the third lens group 63 will cause less load for the driving system, and electric power also can be saved. It is preferable that the expressions (1) to (5) are satisfied as in the first embodiment.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 25.

Table 25

Group	Surface	r	d	n	v
	1	31.758	0.90	1.80518	25.4
	2	15.951	4.50	1.58913	61.2
1	3	−135.286	0.15		
	4	14.102	3.00	1.58913	61.2
	5	45.000	Variable		
	6	45.000	0.50	1.77250	49.6
	7	4.188	2.36		
2	8	−6.630	0.70	1.60602	57.4
	9	5.382	1.75	1.80518	25.4
	10	88.671	Variable		
	11	6.731	3.50	1.60602	57.4
3	12	−11.394	0.50		
	13	12.785	1.70	1.51633	54.1
	14	−350.000	0.50	1.84666	25.4
	15	5.875	Variable		
4	16	7.945	1.95	1.51450	63.1
	17	−28.581	Variable		
5	18	∞	3.70	1.51633	64.1
	19	∞	—		

The following Table 26 shows aspherical shapes of the zoom lens in the present example.

Table 26

Surface	8	11	12	16
K	-3.79187	-1.49571	-5.54316	-2.04960
D	-1.52553×10^{-3}	6.24513×10^{-5}	9.21711×10^{-6}	3.68450×10^{-4}
E	-4.26600×10^{-6}	-3.45653×10^{-6}	-4.27080×10^{-6}	-8.68455×10^{-6}
F	-1.29623×10^{-6}	1.02115×10^{-7}	1.47247×10^{-7}	-2.70755×10^{-9}

The following Table 27 shows zooming distance and shifting amount.

Table 27

	Wide-angle end	Standard position	Telephoto end
f	4.355	23.464	48.623
F/NO	1.857	2.096	2.490
ω	28.579	5.415	2.638
d5	0.500	10.344	12.893
d10	14.415	4.597	2.049
d15	7.262	2.393	5.880
d17	1.012	5.880	2.393
Y	0.034	0.195	0.392
Expression (2)	0.970	1.027	1.000

As shown in Table 27, a shift of the third lens group satisfies the expressions (1) and (2), and it achieves optical performance with less deterioration when compared to a stationary state.

As shown in the following Table 28, the focal length f3 of the third lens group satisfies the expression (3), and thus, a small zoom lens is realized.

Table 28

fw	f3	Expression (3) (f3/fw)
4.350	11.317	2.60

In this embodiment, a lens of the third group, which is positioned closest to the object, has aspherical surfaces on both sides. Especially, the local radius of curvature R10 in the vicinity of the object side and the local radius of curvature R11 in an outer peripheral portion have values shown in the following Table 29, and satisfy the expression (4). As a result, the embodiment achieves excellent aberration performance not only in a stationary state but when correcting camera shake, and especially, aspherical aberration is corrected satisfactorily.

Table 29

R10	R11	Expression (4) (R11/R10)
6.731	12.417	1.85

Furthermore, the object-side surface of a lens of the fourth group is aspherical, a local radius of curvature R20 in the vicinity of an optical axis and a local radius of curvature R11 in an outer peripheral portion have the values shown in Table 30. Moreover, the expression (5) satisfied, excellent aberration performance is realized not only in its stationary state but at correcting. Especially a satisfactory coma aberration is realized.

Table 30

R20	R21	Expression (5) (R21/R20)
7.945	11.021	1.39

FIGs. 30 to 32 show various aberrations at the wide-angle end, the standard position, and the telephoto end of the zoom lens shown in Table 25. FIG. 33 shows an aberration at a telephoto end at a correction of 0.5 degrees. As indicated in FIGs. 30-33, a zoom lens according to this embodiment provides a satisfactory aberration performance.

(Eighth Embodiment)

FIG. 34 is a view showing the arrangement of a zoom lens in a seventh embodiment according to the present invention. As shown in FIG. 34, a zoom lens has a structure in which a first lens group 111, a second lens group 112, a third lens group 113, a fourth lens group 114, and a plate 115 equivalent to an optical low-pass filter and a face plate of a CCD are disposed from an object side to an image plane side in this order.

The first lens group 111 has a positive refracting power, and is fixed with respect to the image plane 116 in varying power and focusing. The second lens group 112 has a negative refracting power and varies power by moving along an optical axis.

The third lens group 113 is composed of three lenses: a positive lens, a negative lens, and a positive lens disposed from the object side in this order, and is fixed with respect to the image plane 306 in varying power and focusing. The fourth lens group 114 is composed of one positive lens, and moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power.

When camera shake occurs, shake of an image is corrected by moving the third lens group 113 vertically with respect to the optical axis direction. Since the third lens group 113 is smaller in lens diameter than the first lens group 111, correction by moving the third lens group 113 will cause less load for the driving system, and electric power also can be saved. It is preferable that the expressions (1) to (5) are satisfied as in the fifth and sixth embodiments.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 31. The first and second lens groups in these embodiments are the same as shown in Table 19.

Table 31

Group	Surface	r	d	n	v
3	11	6.854	3.95	1.51450	63.1
	12	−7.934	1.20		
	13	−10.797	0.50	1.78472	25.7
	14	16.985	0.86		
	15	−21.096	2.00	1.51895	57.3
	16	−6.963	Variable		
4	17	9.141	1.90	1.51450	63.1
	18	335.606	Variable		
5	19	∞	3.70	1.51633	64.1
	20	∞	—		

The following Table 32 shows aspherical shapes of the zoom lens in the present example.

Table 32

Surface	8	1 1	1 2	1 7
K	-3.46709	-1.99011	-3.12036	-1.04888
D	-1.36790×10^{-3}	2.73697×10^{-4}	2.30462×10^{-5}	1.27223×10^{-4}
E	-1.82278×10^{-5}	-2.65163×10^{-6}	1.73552×10^{-6}	-1.69913×10^{-7}
F	-5.96614×10^{-7}	2.37367×10^{-7}	1.42772×10^{-7}	-4.55207×10^{-8}

The following Table 33 shows zooming distance and shifting amount.

Table 33

	Wide-angle end	Standard position	Telephoto end
f	4.246	21.577	47.769
F/NO	1.859	2.003	2.426
ω	29.455	5.923	2.694
d 5	0.500	10.344	12.893
d 1 0	14.442	4.597	2.049
d 1 5	7.261	2.300	5.779
d 1 7	1.013	5.973	2.495
Y	0.031	0.161	0.347
Expression (2)	1.012	1.027	1.000

As shown in Table 33, a shift of the third lens group satisfies the expressions (1) and (2), and it provides an optical performance with less deterioration when compared to a stationary state.

As shown in the following Table 34, the focal length f3 of the third lens group satisfies the expression (3), and achieves a small zoom lens.

Table 34

fw	F3	Expression (3) (f3/fw)
4.246	13.079	3.08

In this example, a lens of the third group, which is positioned closest

to the object, has aspherical surfaces on both sides. Especially, the local radius of curvature R10 in the vicinity of the object-side and the local radius of curvature R11 in an outer peripheral portion have values shown in the following Table 35, and satisfy the expression (4). As a result, the embodiment realizes excellent aberration performance not only in a stationary state but when correcting camera shake, and especially, aspherical aberration is corrected satisfactorily.

Table 35

R10	R11	Expression (4) (R11/R10)
6.854	8.352	1.22

Furthermore, the object-side surface of a lens of the fourth group is aspherical, a local radius of curvature R20 in the vicinity of an optical axis and a local radius of curvature R11 in an outer peripheral portion have the values shown in Table 36. Moreover, the expression (5) is satisfied, excellent aberration performance is realized not only in its stationary state but when correcting camera shake. Especially a satisfactory coma aberration is achieved.

Table 36

R20	R21	Expression (5) (R21/R20)
9.141	10.416	1.14

FIGs. 35 to 37 show various aberrations at the wide-angle end, the standard position, and the telephoto end of the zoom lens shown in Table 31. FIG. 38 shows an aberration at a telephoto end at a correction of 0.5 degrees. As indicated in FIGs. 35-38, a zoom lens according to this embodiment provides a satisfactory aberration performance.

(Ninth Embodiment)

FIG. 39 is a view showing the arrangement of a zoom lens in a ninth embodiment according to the present invention. As shown in FIG. 39, a zoom lens has a structure in which a first lens group 161, a second lens group 162, a third lens group 163, a fourth lens group 164, and a plate 165 equivalent to an optical low-pass filter and a face plate of a CCD are disposed from an object side to an image plane side in this order.

The first lens group 161 has a positive refracting power, and is fixed

with respect to the image plane 166 in varying power and focusing. The second lens group 162 has a negative refracting power and varies power by moving along an optical axis. The third lens group 163 is composed of three lenses: a positive lens, a negative lens, and a positive lens disposed from the object side in this order, and two of the lenses at the image plane side compose a cemented lens of a negative lens and a positive lens.

The third lens group 163 is fixed with respect to the image plane 166 in varying power and focusing. The fourth lens group 164 is composed of one positive lens. The fourth lens group 164 moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power.

When camera shake occurs, shake of an image is corrected by moving the third lens group 163 vertically with respect to the optical axis direction. Since the third lens group 163 is smaller in lens diameter than the first lens group 161, correction by moving the third lens group 163 will cause less load for the driving system, and electric power also can be saved.

It is preferable that the expressions (1) to (5) are satisfied as in the sixth to eighth embodiments.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 37. The first and second lens groups in this embodiment are the same as shown in Table 19.

Table 37

Group	Surface	r	d	n	v
3	11	9.762	3.00	1.51450	63.1
	12	−11.531	1.20		
	13	13.057	0.50	1.75520	27.5
	14	−8.967	3.10	1.53358	51.6
	15	−6.963	Variable		
4	16	15.087	1.80	1.51450	63.1
	17	−51.013	Variable		
5	18	∞	3.70	1.51633	64.1
	19	∞	−		

The following Table 38 shows aspherical coefficients of the zoom lens in the present example.

Table 38

Surface	8	11	12	17
K	-3.46709	-3.79890	-1.61290	-2.22934
D	-1.36790×10^{-3}	1.01179×10^{-4}	4.06410×10^{-5}	-1.33735×10^{-5}
E	-1.82278×10^{-5}	-6.62306×10^{-7}	8.30510×10^{-7}	1.01922×10^{-6}
F	-5.96614×10^{-7}	1.67378×10^{-7}	1.66830×10^{-7}	3.34079×10^{-8}

The following Table 39 shows zooming distance and shifting amount.

Table 39

	Wide-angle end	Standard position	Telephoto end
f	4.224	22.092	47.644
F/NO	1.823	2.112	2.441
ω	29.569	5.749	2.672
d5	0.500	10.344	12.893
d10	14.442	4.597	2.049
d15	7.260	1.815	5.657
d17	1.014	6.459	2.617
Y	0.030	0.150	0.332
Expression (2)	1.016	0.974	1.000

As shown in Table 39, the shifting amount of the third lens group satisfies the expressions (1) and (2), and thus, the optical performance deteriorates less when compared to a stationary state.

As shown in the following Table 40, the focal length f3 of the third lens group satisfies the expression (3), and thus, a small zoom lens is achieved.

Table 40

Fw	f3	Expression (3) (f3/fw)
4.224	13.100	3.10

In this embodiment, a lens of the third group, which is disposed closest to the object, has aspherical surfaces at both sides. Especially, the local radius of curvature R10 in the vicinity of an optical axis at the object-side and the local radius of curvature R11 in an outer peripheral portion have values shown in the following Table 41, and satisfy the expression (4). As a result, the embodiment realizes excellent aberration performance not only in the stationary state but when correcting camera shake, and especially, aspherical aberration is corrected satisfactorily.

Table 41

R10	R11	Expression (4) (R11/R10)
9.762	10.339	1.06

Furthermore, the object-side surface of a lens included in the fourth lens group is aspherical, a local radius of curvature R20 in the vicinity of an optical axis and a local radius of curvature R21 in an outer peripheral portion have the values shown in Table 42. Moreover, the expression (5) is satisfied, and excellent aberration performance is realized not only in its stationary state but when correcting camera shake. Especially, a satisfactory coma aberration is achieved.

Table 42

R20	R21	Expression (5) (R21/R20)
15.087	16.164	1.07

FIGs. 40 to 42 show various aberrations at the wide-angle end, the standard position, and the telephoto end of the zoom lens shown in Table 37. FIG. 43 shows an aberration at a telephoto end at a correction of 0.5 degrees. As indicated in FIGs. 40-43, a zoom lens according to this embodiment provides satisfactory aberration performance.

(Tenth Embodiment)

FIG. 44 shows a video camera in one embodiment of the present invention. The video camera is composed of a first lens group of a zoom lens shown in the sixth to tenth embodiments, a second lens group 211, a third lens

group 212, a fourth lens group 213, an imager 214, a signal processing circuit 215, a camera-shake detecting system 216, and a driving system 217 for correcting camera shake. As a result, a small video camera having an excellent function for correcting camera shake can be provided.

(Eleventh Embodiment)

FIG. 45 is a view to show a basic structure of a zoom lens having a function for correcting camera shake in an eleventh embodiment. As shown in FIG. 45, a zoom lens in this embodiment comprises a first lens group having a positive refracting power and being fixed with respect to an image plane; a second lens group having a negative refracting power and varying power by moving along an optical axis; a third lens group having a positive refracting power and being fixed with respect to the image plane; a fourth lens group having a negative refracting power and being fixed with respect to the image plane; and a fifth lens group having a positive refracting power and moving along an optical axis so as to keep the image plane varied by the a shift of the second lens group and an object at a predetermined position from a reference surface, and the elements are disposed from an object side (left side in FIG. 45) to an image plane side (right side in FIG. 45) in this order. When camera shake occurs, shake of an image is corrected by shifting the third lens group having a positive refracting power in a direction vertical to the optical axis.

FIG. 46 shows a zoom lens having basic elements as shown in FIG. 45. The zoom lens has a structure in which a first lens group 461, a second lens group 462, a third lens group 463, a fourth lens group 464, and a fifth lens group 465 are disposed from an object side to an image plane side in this order.

The first lens group 461 has a positive refracting power, and is fixed with respect to the image plane in varying power and focusing. The second lens group 462 has a negative refracting power and varies power by moving along an optical axis. The third lens group 463 is composed of a positive lens and a negative lens, and has a positive refracting power as a whole.

The fourth lens group 464 is composed of a negative lens and a positive lens, and has a negative refracting power as a whole. It is fixed with respect to the image plane in varying power and focusing. The fifth lens group 465 has a positive refracting power and moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power. When camera shake occurs, shake of an

image is corrected by moving the third lens group 463 vertically with respect to the optical axis.

As described in this embodiment, the third lens group 463 having a positive refracting power and the fourth lens group 464 having a negative refracting power are combined in order to decrease the shifting amount of the shift lens group when correcting camera shake, and to extend the back focus. Especially a long back focus is easy to obtain since a lens group having a negative refracting power is disposed at the image plane side.

Moreover, the performance when shifting the lenses can be improved, and downsizing and high performance are obtainable by applying at least one aspherical surface to any of the lenses of the third group.

It is preferable that the following expressions (6) and (7) are satisfied when $\nu 31$ is Abbe's number of one lens of the third lens group, and $\nu 32$ is Abbe's number of the remaining lens of the third group; $\nu 41$ is Abbe's number of one lens of the fourth lens group, and $\nu 42$ is Abbe's number of the remaining lens of the fourth group.

$$|\nu 31 - \nu 32| > 25 \quad \ldots (6)$$

$$|\nu 41 - \nu 42| > 25 \quad \ldots (7)$$

When the expressions (6) and (7) are satisfied, deterioration in chromatic aberration of magnification when correcting camera shake can be reduced. Chromatic aberration of magnification occurs when correcting camera shake due to lens-shifting, however, deterioration of the chromatic aberration of magnification can be reduced even when shifting a lens since a sufficient effect is obtainable for achromatism by setting differences in the Abbe's number as mentioned above for the respective lens groups.

It is preferable that the following expression (8) is satisfied when the lens for correcting camera shake has an aspherical surface at the object side, and rS1 is a local radius of curvature for a diameter occupying 10% of lens effective diameter, and rS9 is a local radius of curvature for a diameter occupying 90% of lens effective diameter.

$$0.01 < rS1/rS9 < 2.00 \quad \ldots (8)$$

The expression (8) is a conditional expression to determine the aspherical amount, and it indicates a condition to obtain sufficient aberration performance to realize high resolution for a zoom lens. When the value exceeds the upper limit in the Expression (8), the correcting amount for the spherical aberration is excessively decreased. Moreover, coma flares will occur easily when moving the lens. When the value falls below the lower

limit, correction amount of the spherical aberration is excessively increased, and sufficient aberration performance cannot be obtained.

Here, the local radius of curvature C is obtainable through an algebraic calculation based on aspherical coefficients figured out from the sag amount of the plane shape. It is obtainable by the following equations (C) and (D).

$$SAG = \frac{H^2 / R}{1 + \sqrt{1 - (1 + K)(H / R)^2}} + D \cdot H^4 + E \cdot H^6 + F \cdot H^8 + G \cdot H^{10} \qquad \text{(C)}$$

$$C = \frac{\left(1 + \left(\frac{dSAG}{dH}\right)^2\right)\sqrt{1 + \left(\frac{dSAG}{dH}\right)^2}}{\frac{d^2 SAG}{dH^2}} \qquad \text{(D)}$$

SAG: a distance from the apex on the aspherical surface to a point on the same aspherical surface having a height H from the optical axis

H: a height from an optical axis

R is a radius of curvature at the apex on the aspherical surface

K: a conical constant

D, E, F, G: aspherical coefficients.

It is also preferable that the correcting lens satisfies the following Expression (9), when f3 is a focal length of the correcting lens and f34 is a composite focal length of the third and fourth lens groups.

$0.40 < |f3/f34| < 0.85$ ...(9)

The expression (9) is a conditional expression to define the focal length of a lens used for correcting camera shake. When the value falls below the lower limit in the expression (9), the correcting lens will have excessive power, deterioration in the aberration performance is increased and assembling tolerance in manufacturing will be strict. When the value exceeds the upper limit, the shifting amount of the lens when correcting camera shake is increased, and the lens diameter also is increased. This is not favorable for downsizing.

Preferably, the zoom lens satisfies the following expression (10) when fw is a focal length of the entire system at the wide-angle end, and BF is a distance between the final surface of the lens and the image plane in the air.

$2.0<BF/fw<5.0$ ...(10)

The expression (10) is a conditional expression to provide a zoom lens having a long back focus, for example, a zoom lens using three imaging devices. When the value falls below the lower limit, a color separation optical system with sufficient length to conduct a sufficient color separation cannot be inserted. When it exceeds the upper limit, the back focus becomes longer than required, and it will be an obstacle for downsizing.

Preferably, the following expressions (11) to (17) are satisfied when fw is a focal length of the entire system at a wide-angle end, fi (i=1-5) is the focal length of the i-th lens group, and f34 is a composite focal length of the third and fourth focal length.

$5.0<f1/fw<8.0$ ...(11)

$0.5<|f2|/fw<1.6$ ...(12)

$4.0<f34/fw<9.5$ ...(13)

$2.0<f5/fw<5.0$ ...(14)

The expression (11) indicates a condition relating to the refracting power of the first lens group. Since the first lens group has excessive refracting power when the value falls below the lower limit, correction of spherical aberration at the long focal point side becomes difficult. When it exceeds the upper limit, the lens will be long and thus, a compact zoom lens cannot be obtained.

The expression (12) indicates a condition relating to the refracting power of the second lens group. The zoom lens can be made compact when the value falls below the lower limit, however, the Petzval's sum of the entire system will be increased negatively and distortion of the image plane cannot be corrected. The aberration can be corrected easily when the value exceeds the upper limit, however, the variable power system becomes long and the entire system cannot be downsized.

The expression (13) indicates a condition relating to the refracting power of the third lens group. When the value falls below the lower limit, the third lens group will have excessive refracting power, and thus, correction of the spherical aberration will be difficult. When the value exceeds the upper limit, the composite system of the first to third lens group becomes a divergent system. In such a zoom lens, the outer diameter of the lenses of the fourth group positioned behind the first to third groups cannot be decreased, and Petzval's sum of the entire system cannot be decreased.

The expression (14) indicates a condition relating to the refracting

power of the fourth lens group. When the value falls below the lower limit, the coverage of an image will be decreased. For obtaining a desired coverage, the lens diameter of the first group should be increased, and thus, this will be an obstacle for downsizing and weight reduction. When the value exceeds the upper limit, the aberration can be corrected easily. However, the shifting amount of the fourth lens group is increased at a close-range shooting, and thus, the entire system cannot be downsized. Moreover, it is difficult to correct unbalanced off-axis aberrations between short-range and long-range shootings.

It is also preferable that the following expressions (15) and (16) are satisfied when Y is a shifting amount of a correcting lens at a focal length f of the entire system for correcting camera shake, Yt is a shifting amount of the correcting lens at a telephoto end, and ft is a focal length of the telephoto end.

$Yt>Y$ ...(15)

$(Y/Yt)/(f/ft)<1.5$ ...(16)

The expressions (15) and (16) relate to the shifting amount of a correcting lens. For a zoom lens, the shifting amount of the correcting lens is large as the zoom ratio is great, while the same amount is decreased when the zoom ratio is small when the correcting angle is constant within a whole zooming range. When the value exceeds the upper limits of the expressions (15) and (16), overcorrection occurs and the optical performance will deteriorate further.

Specific examples for this embodiment are shown in the following Table 43.

Table 43

Group	Surface	r	d	n	v
1	1	43.712	0.90	1.80518	25.4
	2	22.377	6.00	1.60311	60.7
	3	−147.260	0.20		
	4	20.439	3.50	1.60311	60.7
	5	64.129	Variable		
2	6	47.371	0.60	1.77250	49.6
	7	6.608	3.10		
	8	−8.756	0.80	1.66547	55.2
	9	7.541	1.80	1.84666	23.9
	10	61.377	Variable		
3	11	18.722	2.90	1.60602	57.5
	12	−14.771	0.10		
	13	−61.576	0.70	1.80518	25.4
	14	82.921	2.45		
4	15	−15.486	0.70	1.51633	64.1
	16	21.635	1.65	1.80518	25.4
	17	246.689	Variable		
5	18	−90.847	0.60	1.84666	23.9
	19	12.912	4.10	1.51633	64.1
	20	−18.441	0.10		
	21	15.386	4.50	1.60602	57.5
	22	−15.967	Variable		
6	23	∞	14.00	1.58913	61.2
	24	∞	3.90	1.51633	64.1
	25	∞	—		

The following Table 44 shows aspherical coefficients.

Table 44

Surface	8	11	12	21	22
K	4.65875×10^{-1}	1.42789×10^{-1}	1.14334×10^{-1}	-1.25651	-6.94184×10^{-1}
D	9.66131×10^{-5}	-9.38804×10^{-5}	5.30815×10^{-5}	-1.94414×10^{-5}	2.31291×10^{-5}
E	-7.08756×10^{-6}	6.02667×10^{-6}	5.05125×10^{-6}	5.49746×10^{-7}	2.50059×10^{-7}
F	1.91335×10^{-7}	-2.97812×10^{-7}	-1.94202×10^{-7}	-8.03971×10^{-9}	-6.03441×10^{-9}
G	0.00000	2.28611×10^{-9}	0.00000	0.00000	0.00000

The following Table 45 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens. At the standard position magnification of the second lens group becomes –1 times.

Table 45

	Wide-angle end	Standard position	Telephoto end
f	4.166	23.073	48.386
F/NO	1.680	1.680	1.886
2ω	60.226	11.023	4.354
d5	0.700	15.560	18.886
d10	19.216	4.356	1.030
d14	5.331	1.967	4.258
d19	1.099	4.463	2.172

FIGs. 47-49 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. The values of the expressions (6) to (14) are as follows.

$|\nu31-\nu32|=32.3$

$|\nu41-\nu42|=38.7$

$rS1/rS9=0.52$

$|f3/f34|=0.64$

$BF/fw=3.34$

$f1/fw=7.19$

$|f2|/fw=1.28$

$f34/fw=7.61$

$f5/fw=3.14$

As clearly shown in the aberrations of FIGs. 47-49, this example provides sufficient performance to correct aberration for obtaining high resolution of a zoom lens.

Furthermore, this example is useful in preventing deterioration of the optical performance since the expressions (15) and (16) are satisfied.

Other specific examples according to this embodiment are shown in the following Table 46.

Table 46

Group	Surface	r	d	n	v
	1	45.790	0.90	1.80518	25.4
	2	22.855	5.80	1.60311	60.7
1	3	−137.451	0.15		
	4	20.654	3.15	1.60311	60.7
	5	66.413	Variable		
	6	49.547	0.60	1.51633	64.1
	7	5.943	3.65		
2	8	−8.260	0.80	1.66547	55.2
	9	7.608	2.01	1.84666	23.9
	10	31.856	Variable		
	11	20.308	2.80	1.51450	63.1
3	12	−11.071	0.10		
	13	−32.200	0.70	1.80518	25.4
	14	−179.621	2.45		
	15	−11.566	0.70	1.51450	63.1
4	16	18.674	1.50	1.80518	25.4
	17	−382.316	Variable		
	18	139.563	0.60	1.84666	23.9
	19	11.702	3.70	1.51633	64.1
5	20	−27.808	0.10		
	21	13.425	4.90	1.51450	63.1
	22	−12.590	Variable		
	23	∞	14.00	1.58913	61.2
6	24	∞	3.90	1.51633	64.1
	25	∞	−		

The following Table 47 shows aspherical coefficients.

Table 47

Surface	8	1 1	1 2	2 1	2 2
K	2.65508×10^{-1}	3.81101×10^{-1}	0.00000	-9.36333×10^{-1}	-8.93853×10^{-1}
D	2.27944×10^{-4}	-2.03395×10^{-4}	-2.15420×10^{-5}	-4.92768×10^{-5}	4.67131×10^{-5}
E	-4.63825×10^{-6}	3.74881×10^{-6}	2.89479×10^{-6}	7.98657×10^{-7}	1.88913×10^{-7}
F	1.53384×10^{-7}	-2.17585×10^{-7}	-1.16142×10^{-7}	-1.25522×10^{-8}	-9.70141×10^{-9}
G	0.00000	2.28611×10^{-9}	0.00000	0.00000	0.00000

The following Table 48 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens.

Table 48

	Wide-angle end	Standard position	Telephoto end
f	4.196	23.529	49.156
F/NO	1.668	1.682	1.907
2 ω	59.743	10.822	5.414
d 5	0.700	14.055	17.374
d 1 0	19.204	5.842	2.530
d 1 4	5.831	2.402	4.737
d 1 9	0.995	4.425	2.090

FIGs. 50-52 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. The values of the expressions (6) to (14) are as follows.

$|\nu31-\nu32|=37.7$

$|\nu41-\nu42|=37.7$

$rS1/rS9=0.07$

$|fs/f34|=0.57$

$BF/fw=3.29$

$f1/fw=7.22$

$|f2|/fw=1.28$

$f34/fw=8.40$

$f5/fw=3.15$

As clearly shown in the aberrations of FIGs. 50-52, this example provides sufficient performance to correct aberration to obtain high resolution of a zoom lens. Furthermore, this example is useful in preventing deterioration of the optical performance since the expressions (15) and (16) are satisfied.

Other specific examples according to this embodiment are shown in the following Table 49.

Table 49

Group	Surface	r	d	n	v
1	1	43.258	0.90	1.80518	25.4
	2	22.067	5.80	1.60311	60.7
	3	−141.493	0.15		
	4	20.338	3.15	1.60311	60.7
	5	64.306	Variable		
2	6	46.991	0.60	1.77250	49.6
	7	6.645	3.10		
	8	−8.848	0.80	1.66547	55.2
	9	7.368	1.60	1.84666	23.9
	10	53.923	Variable		
3	11	16.972	2.61	1.60602	57.5
	12	−13.177	0.09		
	13	−55.938	0.70	1.80518	25.4
	14	73.946	2.45		
4	15	−17.219	0.77	1.51633	64.1
	16	22.997	1.82	1.80518	25.4
	17	288.894	Variable		
5	18	−88.752	0.60	1.84666	23.9
	19	12.766	4.50	1.51633	64.1
	20	−18.677	0.10		
	21	15.561	5.00	1.60602	57.6
	22	−16.083	Variable		
6	23	∞	13.00	1.58913	61.2
	24	∞	3.00	1.51633	64.1
	25	∞	—		

The following Table 50 shows aspherical coefficients.

Table 50

Surface	8	11	12	21	22
K	4.747248×10^{-1}	2.101119×10^{-1}	1.007413×10^{-1}	-1.279930	-6.730536×10^{-1}
D	4.453156×10^{-5}	-9.582481×10^{-5}	9.286602×10^{-5}	-9.244688×10^{-6}	3.352961×10^{-5}
E	-7.953517×10^{-7}	1.260729×10^{-6}	1.333902×10^{-7}	-1.306964×10^{-7}	-3.521187×10^{-7}
F	-5.757966×10^{-8}	-2.487044×10^{-7}	-5.579667×10^{-8}	9.358746×10^{-10}	1.832323×10^{-9}
G	0.000000	5.900849×10^{-9}	0.000000	0.000000	0.000000

The following Table 51 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens.

Table 51

	Wide-angle end	Standard position	Telephoto end
f	4.256	22.469	49.343
F/NO	1.697	1.695	1.902
2ω	59.068	11.284	5.401
d5	0.700	14.053	17.391
d10	19.212	5.867	2.530
d14	5.831	2.537	4.742
d19	0.855	4.149	1.944

FIGs. 53-55 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. The values of the expressions (6) to (14) are as follows.

$|\nu31-\nu32|=32.3$

$|\nu41-\nu42|=38.6$

$rS1/rS9=0.58$

$|f3/f34|=0.72$

$BF/fw=2.93$

$f1/fw=6.97$

$|f2|/fw=1.26$

$f34/fw=5.89$

$f5/fw=3.11$

As clearly shown in the aberrations of FIGs. 53-55, this example provides sufficient performance to correct aberration to obtain high resolution of a zoom lens. Furthermore, this example is useful in preventing deterioration of the optical performance since the expressions (15) and (16) are satisfied.

(Twelfth Embodiment)

FIG. 56 is a view showing the arrangement of a zoom lens in a twelfth embodiment according to the present invention. As shown in FIG. 56, a zoom lens has a structure in which a first lens group 1a, a second lens group 2a, a third lens group 3a, a fourth lens group 4a and a fifth lens group 5a are disposed from an object side in this order. The first lens group 1a has a positive refracting power and is fixed with respect to the image plane. The second lens group 2a has a negative refracting power and varies power by moving along an optical axis. The third lens group 3a is fixed with respect to the image plane and has a negative refracting power. The fourth lens group 4a is fixed with respect to the image plane and has a positive refracting power. The fifth lens group 5a has a positive refracting power and moves along an optical axis to keep the image plane varied by the shift of the second lens group and the object at a predetermined position from a reference surface. Camera shake is corrected by shifting the fourth lens group having a positive refracting power in a direction vertical to the optical axis.

FIG. 57 shows a zoom lens of the basic structure shown in FIG. 56. The zoom lens has a structure in which a first lens group 121, a second lens group 122, a third lens group 123, and a fourth lens group 124 are disposed from the object side to the image plane side in this order. The first lens group 121 has a positive refracting power, and is fixed with respect to the image plane in varying power and focusing. The second lens group 122 has a negative refracting power and varies power by moving along an optical axis.

The third lens group 123 is composed of a negative lens and a positive lens, and has a negative refracting power as a whole. The fourth lens group 124 is composed of a positive lens and a negative lens, and has a positive refracting power as a whole. The group is fixed with respect to the image plane in varying power and focusing. A fifth lens group 125 has a positive refracting power, and moves along an optical axis so as to move an image and

adjust the focus thereof at the same time in accordance with variable power. When camera shake occurs, shake of an image is corrected by moving the fourth lens group 124 vertically with respect to the optical axis.

As described above, light beams entering the fifth lens group 125 can be lowered by combining the third lens group 123 having a negative refracting power and a fourth lens group 124 having a positive refracting power. Namely, the lens diameter of the fourth group can be decreased and a load on an actuator will be decreased in focusing.

The performance when shifting the lenses can be improved by applying at least one aspherical surface to any of the lenses of the fourth group. Similar to the eleventh embodiment, it is preferable that the expressions (6)-(16) are satisfied.

Specific examples for this embodiment are shown in the following Table 52.

Table 52

Group	Surface	r	d	n	v
1	1	43.700	0.90	1.80518	25.4
	2	22.310	6.00	1.60311	60.7
	3	−147.017	0.20		
	4	20.415	3.50	1.60311	60.7
	5	64.027	Variable		
2	6	64.027	0.60	1.77250	49.6
	7	6.600	3.10		
	8	−8.963	0.80	1.66547	55.2
	9	6.685	1.80	1.80518	25.4
	10	65.269	Variable		
3	11	−19.604	0.70	1.51633	64.1
	12	24.259	1.65	1.84666	23.9
	13	100.263	1.00		
4	14	12.130	3.51	1.60602	57.6
	15	−14.418	0.10		
	16	−42.218	0.60	1.80518	25.4
	17	56.648	Variable		
5	18	−106.725	0.70	1.80518	25.4
	19	16.919	3.60	1.51633	64.1
	20	−23.864	0.10		
	21	18.527	3.60	1.60602	57.6
	22	−22.813	Variable		
6	23	∞	14.00	1.58913	61.2
	24	∞	3.90	1.51633	64.1
	25	∞	−		

The following Table 53 shows aspherical coefficients.

Table 53

Surface	8	1 1	1 2	2 1	2 2
K	5.37219×10^{-1}	2.97152×10^{-1}	-2.48406	-5.61162	-5.96501
D	8.69130×10^{-5}	-1.56550×10^{-4}	2.68507×10^{-5}	5.63851×10^{-5}	-4.80942×10^{-5}
E	-5.67323×10^{-6}	6.96463×10^{-8}	3.64998×10^{-7}	-2.49399×10^{-7}	3.72704×10^{-7}

The following Table 54 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens.

Table 54

	Wide-angle end	Standard position	Telephoto end
f	4.029	23.328	50.226
F/NO	1.650	1.776	1.966
2 ω	62.566	10.893	5.239
d 5	0.700	14.408	17.686
d 1 0	20.216	6.509	3.230
d 1 4	5.331	1.876	4.155
d 1 9	1.200	4.636	2.184

FIGs. 58-60 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. The values of the expressions (6) to (14) are as follows.

$|\nu31-\nu32|=40.2$

$|\nu41-\nu42|=32.3$

$rS1/rS9=0.74$

$|f3/f34|=0.69$

$BF/fw=3.45$

$f1/fw=7.43$

$|f2|/fw=1.29$

$f34/fw=6.20$

$f5/fw=4.19$

As clearly shown in the aberrations of FIGs. 58-60, this example provides sufficient performance to correct aberration to obtain high resolution of a zoom lens. Furthermore, this example is useful in preventing deterioration of the optical system since the expressions (15) and (16) are satisfied.

(Thirteenth Embodiment)

FIG. 61 is a view showing the arrangement of a zoom lens in a twelfth embodiment according to the present invention. As shown in FIG. 61, a zoom lens has a structure in which a first lens group 161, a second lens group 162, a third lens group 163, and a fourth lens group 164 are disposed from an object side to an image plane side in this order. The first lens group 161 has a positive refracting power, and is fixed with respect to the image plane in varying power and focusing. The second lens group 162 has a negative refracting power and varies power by moving along an optical axis.

The third lens group 163 is a cemented lens composed of two lenses and it has a positive refracting power. The fourth lens group 164 has a negative refracting power and is fixed with respect to the image plane in varying power and focusing. A fifth lens group 165 has a positive refracting power and moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power. When camera shake occurs, shake of an image is corrected by moving the third lens group 163 vertically with respect to the optical axis. The tolerance can be eased by making the shift lens group 163 a cemented lens.

Performance when shifting the lenses can be improved by applying at least one aspherical surface to any of the lenses of the third group. Similar to the eleventh embodiment, it is preferable that the expressions (6)-(18) are satisfied.

Specific examples for this embodiment are shown in the following Table 55.

Table 55

Group	Surface	r	d	n	v
1	1	43.712	0.90	1.80518	25.4
	2	22.377	6.00	1.60311	60.7
	3	−147.260	0.20		
	4	20.439	3.50	1.60311	60.7
	5	64.129	Variable		
2	6	47.371	0.60	1.77250	49.6
	7	6.608	3.10		
	8	−8.756	0.80	1.66547	55.2
	9	7.541	1.80	1.84666	23.9
	10	61.377	Variable		
3	11	11.304	2.00	1.60602	57.5
	12	29.656	1.00	1.80518	25.4
	13	71.482	2.45		
4	14	−45.255	0.70	1.51633	64.1
	15	13.342	1.65	1.80518	25.4
	16	23.203	Variable		
5	17	−88.752	0.60	1.84666	23.9
	18	12.766	4.10	1.51633	64.1
	19	−18.677	0.10		
	20	15.561	4.50	1.60602	57.6
	21	−16.083	Variable		
6	22	∞	14.00	1.58913	61.2
	23	∞	3.90	1.51633	64.1
	24	∞	—		

The following Table 56 shows aspherical coefficients.

Table 56

Surface	8	11	12	21	22
K	4.65875×10^{-1}	1.42789×10^{-1}	1.14334×10^{-1}	-1.256510	-6.94184×10^{-1}
D	9.66131×10^{-5}	2.50260×10^{-4}	3.81894×10^{-4}	-2.86326×10^{-5}	-1.87081×10^{-5}
E	-7.08756×10^{-7}	9.98537×10^{-6}	1.14292×10^{-5}	4.11743×10^{-7}	1.01992×10^{-7}
F	1.91335×10^{-7}	-2.16512×10^{-7}	-1.11482×10^{-7}	-9.63753×10^{-9}	-5.68100×10^{-9}
G	0.00000	2.28611×10^{-9}	0.00000	0.00000	0.00000

The following Table 57 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens.

Table 57

	Wide-angle end	Standard position	Telephoto end
f	4.153	23.052	48.765
F/NO	1.853	1.952	1.877
2ω	60.636	11.025	5.426
d5	0.700	14.060	17.386
d10	19.216	5.856	2.530
d14	5.331	1.967	4.261
d19	1.200	4.846	2.532

FIGs. 62-64 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. The values of the expressions (6) to (14) are as follows.

$|v31-v32|=32.3$

$|v41-v42|=38.6$

$rS1/rS9=1.49$

$|f3/f34|=0.66$

$BF/fw=3.36$

$f1/fw=7.21$

$|f2|/fw=1.29$
$f34/fw=7.35$
$f5/fw=2.96$

As clearly shown in the aberrations of FIGs. 62-64, this example provides sufficient performance to correct aberration to obtain high resolution of a zoom lens. Furthermore, this example is useful in preventing deterioration of the optical performance since the expressions (15) and (16) are satisfied.

(Fourteenth Embodiment)

This embodiment relates to a video camera using three imaging devices where the video camera has a function to correct camera shake by using a zoom lens in any of the eleventh to thirteenth embodiments, and the structure is shown in FIG. 65.

A video camera according to this embodiment comprises a zoom lens 201 of the eleventh embodiment, a low-pass filter 202, prisms 203a-203c for color separation, imagers 204a-204c, a signal processing circuit 205, a view finder 206, a sensor 207 for detecting camera shake, and an actuator 208 for driving the lens.

The zoom lens is not limited to what is shown in the tenth embodiment, but zoom lenses described in the twelfth and thirteenth embodiments also can be used, though they are not shown specifically in any figures.

Although the shift lens group is composed of two single lenses in the eleventh to thirteenth embodiments, the lenses can be a cemented lens to ease the tolerance.

Although camera shake is corrected by shifting a lens group having a positive refracting power in the eleventh to thirteenth embodiments, similar effects can be obtained by shifting a lens group having a negative refracting power.

(Fifteenth Embodiment)

FIG. 66 is a view showing the arrangement of a zoom lens in a fifteenth embodiment according to the present invention. As shown in FIG. 66, a zoom lens has a structure in which a first lens group 21, a second lens group 22, a third lens group 23, a fourth lens group 24, and a fifth lens group 25 are disposed from an object side (left side in FIG. 66) to an image plane side (right side in FIG. 66) in this order.

The first lens group 21 has a positive refracting power and is fixed

with respect to the image plane in varying power and focusing. The second lens group 22 has a negative refracting power and varies power by moving along an optical axis. The third lens group 23 is composed of three lenses: a negative lens, a positive lens and a positive lens disposed from the object side in this order. This group includes at least one aspherical surface and has a positive refracting power as a whole.

The fourth lens group 24 is composed of two lenses as a cemented lens of a negative lens and a positive lens disposed from the object side in this order and it has a negative refracting power as a whole, and is fixed with respect to the image plane in varying power and focusing. The fifth lens group 25 has a positive refracting power and moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with the variable power. When camera shake occurs, shake of an image is corrected by moving the third lens group 23 vertically with respect to the optical axis.

The performance when shifting the lenses can be improved by applying at least one aspherical surface to any of the lenses of the third group 23.

It is preferable that the above-described expression (8) about aspherical surface amount is satisfied for the third lens group 23 when r31 represents a local radius of curvature for a diameter occupying 10% of the lens effective diameter, and r39 is a local radius of curvature for a diameter occupying 90% of lens effective diameter.

Here, the local radius of curvature C is obtainable through an algebraic calculation based on aspherical coefficients figured out from the sag amount of the plane shape. It is obtainable by the following equations (E) and (F).

$$SAG = \frac{H^2/R}{1+\sqrt{1-(1+K)(H/R)^2}} + D\cdot H^4 + E\cdot H^6 \qquad \text{(E)}$$

$$C = \frac{\left(1+\left(\frac{dSAG}{dH}\right)^2\right)\sqrt{1+\left(\frac{dSAG}{dH}\right)^2}}{\frac{d^2SAG}{dH^2}} \qquad \text{(F)}$$

SAG: a distance from the apex on the aspherical surface to a point on the same aspherical surface having a height H from the optical axis
H: a height from an optical axis
R is a radius of curvature at the apex on the aspherical surface
K: a conical constant
D, E: aspherical coefficients
C: local radius of curvature

It is also preferable that the correcting lens satisfies the expression (9), when f3 is the focal length of the third lens group 23 (a correcting lens group) and f34 is a composite focal length of the third and fourth lens groups.

Preferably, the expression (10) is satisfied when fw is a focal length of the entire system at the wide-angle end, and BF is a distance between the final surface of the lens and the image plane in the air.

Preferably, the expressions (11) to (14) are satisfied when fw is a focal length of the entire system at a wide-angle end, fi (i=1-5) is the focal length of the i-th lens group, and f34 is a composite focal length of the third and fourth lens group 23, 24.

It is also preferable that the expressions (15) and (16) are satisfied when Y is a shifting amount of the third lens group 23 at a focal length f of the entire system when correcting camera shake, Yt is a shifting amount of the third lens group 23 at the telephoto end, and ft is a focal length of the telephoto end.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 58.

Table 58

Group	Surface	r	d	n	ν
1	1	35.243	0.90	1.80518	25.4
	2	18.353	5.25	1.60311	60.7
	3	−154.339	0.15		
	4	17.449	3.00	1.60311	60.7
	5	53.989	Variable		
2	6	53.989	0.70	1.78500	43.7
	7	5.142	2.97		
	8	−7.948	0.80	1.66547	55.2
	9	5.519	2.70	1.80518	25.4
	10	1291.253	Variable		
3	11	136.351	1.00	1.84666	23.9
	12	24.057	0.50		
	13	16.099	1.70	1.51450	63.1
	14	−199.059	0.50		
	15	48.853	1.90	1.58913	61.2
	16	−18.181	2.70		
4	17	−22.167	0.80	1.58913	61.2
	18	12.517	1.60	1.80518	25.4
	19	52.330	Variable		
5	20	−42.760	0.60	1.84666	23.9
	21	15.607	2.80	1.51633	64.1
	22	−14.704	0.10		
	23	12.767	3.00	1.51450	63.1
	24	−16.499	Variable		
6	25	∞	14.00	1.58913	61.2
	26	∞	2.80	1.51633	64.1
	27	∞	—		

The following Table 59 shows aspherical coefficients of the zoom lens in the present example.

Table 59

Surface	8	13	22
K	−4.89985	−8.46317	−1.14637
D	-1.08175×10^{-3}	1.00945×10^{-4}	-6.03706×10^{-5}
E	-1.06040×10^{-5}	-1.63114×10^{-6}	-8.33884×10^{-8}

The following Table 60 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of

the lens. At the standard position, magnification of the second lens group 22 becomes −1 times in Table 60.

Table 60

	Wide-angle end	Standard position	Telephoto end
f	3.680	17.737	42.686
F/NO	1.658	1.914	2.072
2ω	58.508	12.362	5.106
d5	0.600	11.675	14.927
d10	17.903	6.827	3.575
d14	5.200	2.519	5.200
d19	1.000	3.682	1.000

The values of the expressions (9) to (14) are as follows.

$rS1/rS9=0.64$

$|f3/f34|=0.59$

$BF/fw=4.09$

$f1/fw=7.00$

$|f2|/fw=1.25$

$f34/fw=9.14$

$f5/fw=3.79$

In this example, the above-described expression (8) is satisfied, and a sufficient aberration performance is provided to realize high resolution. Since the expression (9) is satisfied, deterioration in the aberration performance can be decreased and assembly tolerance in manufacturing can be eased. Moreover, since the shifting amount of the lenses is decreased when correcting camera shake, the lens diameter can be reduced for downsizing. Furthermore, since the expression (10) is satisfied, a color separation optical system having a length for a sufficient color separation can be inserted.

Furthermore, the back focus does not need to have extra length, and a small zoom lens can be provided. Since the expressions (11) to (14) are satisfied, the aberration can be corrected easily and the zoom lens can be downsized.

FIGs. 67-69 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. As clearly shown in the aberrations of FIGs. 67-69, this example provides sufficient performance to correct aberration to obtain high resolution of a zoom lens.

(Sixteenth Embodiment)

FIG. 70 is a view showing the arrangement of a zoom lens in a sixteenth embodiment according to the present invention. As shown in FIG. 70, a zoom lens has a structure in which a first lens group 701, a second lens group 702, a third lens group 703, a fourth lens group 704, and a fifth lens group 705 are disposed from an object side (left side in FIG. 70) to an image plane side (right side in FIG. 70) in this order.

The first lens group 701 has a positive refracting power and is fixed with respect to the image plane in varying power and focusing. The second lens group 702 has a negative refracting power and varies power by moving along an optical axis.

The third lens group 703 is composed of three lenses: a negative lens, a positive lens and a positive lens disposed from the object side in this order. This group includes at least one aspherical surface and has a positive refracting power as a whole.

The fourth lens group 704 is composed of two lenses as a cemented lens of a negative lens and a positive lens disposed from the object side in this order and this group has a negative refracting power as a whole, and is fixed with respect to the image plane in varying power and focusing. The fifth lens group 705 has a positive refracting power and moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power. When camera shake occurs, shake of an image is corrected by moving the third lens group 703 vertically with respect to the optical axis.

The performance at shifting the lenses can be improved by applying at least one aspherical surface to any of the lenses of the third group 703.

Similar to the fifteenth embodiment, it is preferable for the zoom lens of this embodiment that the conditional expressions (8)-(16) are satisfied.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 61.

Table 61

Group	Surface	r	d	n	ν
1	1	35.243	0.90	1.80518	25.4
	2	18.353	5.25	1.60311	60.7
	3	−154.339	0.15		
	4	17.449	3.00	1.60311	60.7
	5	53.989	Variable		
2	6	53.989	0.70	1.78500	43.7
	7	5.142	2.97		
	8	−7.948	0.80	1.66547	55.2
	9	5.519	2.70	1.80518	25.4
	10	1291.253	Variable		
3	11	58.041	1.00	1.51450	63.1
	12	−19.193	0.50		
	13	−18.810	1.70	1.84666	23.9
	14	−59.301	0.50		
	15	43.566	1.90	1.58913	61.2
	16	−17.985	2.70		
4	17	−20.041	0.80	1.58913	61.2
	18	12.918	1.60	1.80518	25.4
	19	63.402	Variable		
5	20	−51.268	0.60	1.84666	23.9
	21	15.447	2.80	1.51633	64.1
	22	−14.704	0.10		
	23	12.767	3.00	1.51450	63.1
	24	−16.499	Variable		
6	25	∞	14.00	1.58913	61.2
	26	∞	2.80	1.51633	64.1
	27	∞	—		

The following Table 62 shows aspherical coefficients of the zoom lens in the present example.

Table 62

Surface	8	13	22
K	−4.89985	−8.44752	-9.50310×10^{-1}
D	-1.08175×10^{-3}	-4.24504×10^{-5}	-4.89670×10^{-5}
E	-1.06040×10^{-5}	7.84853×10^{-7}	-6.72180×10^{-8}

The following Table 63 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of

the lens. At the standard position, magnification of the second lens group 62 becomes –1 times in Table 63.

Table 63

	Wide-angle end	Standard position	Telephoto end
f	3. 691	17. 802	42. 813
F/NO	1. 657	1. 925	2. 078
2ω	58. 349	12. 321	42. 813
d5 d10 d14 d19	0. 600 17. 903 5. 200 1. 000	11. 675 6. 827 2. 485 3. 715	14. 927 3. 575 5. 200 1. 000

The values of the expressions (12) to (19) are as follows.

rS1/rS9=0.63

| f3/f34 | =0.59

BF/fw=4.01

f1/fw=6.98

| f2 | /fw=1.25

f34/fw=9.17

f5/fw=3.70

FIGs. 71-73 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. As clearly shown in the aberrations of FIGs. 72-74 and FIG. 7-9, a zoom lens according to this embodiment has sufficient performance to correct aberration to realize high resolution.

(Seventeenth Embodiment)

FIG. 74 is a view showing the arrangement of a zoom lens in a seventeenth embodiment according to the present invention. As shown in FIG. 74, a zoom lens has a structure in which a first lens group 101, a second lens group 102, a third lens group 103, a fourth lens group 104, and a fifth lens group 105 are disposed from an object side (left side in FIG. 74) to an image plane side (right side in FIG. 74) in this order.

The first lens group 101 has a positive refracting power and is fixed

with respect to the image plane in varying power and focusing. The second lens group 102 has a negative refracting power and varies power by moving along an optical axis. The third lens group 103 is composed of three lenses: a positive lens, a positive lens and a negative lens disposed from the object side in this order. The third lens group includes at least one aspherical surface and has a positive refracting power as a whole. The fourth lens group 104 is composed of two lenses as a cemented lens of a negative lens and a positive lens disposed from the object side in this order, and this group has a negative refracting power as a whole, and is fixed with respect to the image plane in varying power and focusing. The fifth lens group 105 has a positive refracting power and moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power. When camera shake occurs, shake of an image is corrected by moving the third lens group 103 vertically with respect to the optical axis.

As mentioned above, the performance when shifting the lenses can be improved by applying at least one aspherical surface to any of the lenses of the third group 63.

Similar to the first embodiment, it is preferable for the zoom lens of this embodiment that the conditional expressions (8)-(16) are satisfied.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 64.

Table 64

Group	Surface	r	d	n	ν
1	1	35.243	0.90	1.80518	25.4
	2	18.353	5.25	1.60311	60.7
	3	−154.339	0.15		
	4	17.449	3.00	1.60311	60.7
	5	53.989	Variable		
2	6	53.989	0.70	1.78500	43.7
	7	5.142	2.97		
	8	−7.948	0.80	1.66547	55.2
	9	5.519	2.70	1.80518	25.4
	10	1291.253	Variable		
3	11	1044.254	1.70	1.51450	63.1
	12	−16.361	0.10		
	13	15.774	1.90	1.58913	61.2
	14	−45.969	0.50		
	15	−46.430	1.90	1.80518	25.4
	16	42.087	2.70		
4	17	−20.461	0.80	1.58913	61.2
	18	16.458	1.60	1.80518	25.4
	19	63.911	Variable		
5	20	−54.786	0.60	1.84666	23.9
	21	18.645	2.80	1.51633	64.1
	22	−12.273	0.10		
	23	11.361	3.00	1.51450	63.1
	24	−19.962	Variable		
6	25	∞	14.00	1.58913	61.2
	26	∞	2.80	1.51633	64.1
	27	∞	—		

The following Table 65 shows aspherical coefficients of the zoom lens in the present example.

Table 65

Surface	8	13	22.
K	−4.89985	−4.53315	-8.12542×10^{-1}
D	-1.08175×10^{-3}	-6.30517×10^{-5}	-5.78738×10^{-5}
E	-1.06040×10^{-5}	2.50225×10^{-7}	-1.83558×10^{-7}

The following Table 66 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of

the lens. At the standard position magnification of the second lens group 102 becomes –1 times in Table 65.

Table 66

	Wide-angle end	Standard position	Telephoto end
f	3.685	18.123	42.738
F/NO	1.657	1.879	2.074
2ω	58.363	12.121	5.093
d5 d10 d14 d19	0.600 17.902 5.200 1.000	11.675 6.827 2.329 3.871	14.927 3.575 5.200 1.000

FIGs. 75-77 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. As clearly shown in the aberrations of FIGs. 75-77, a zoom lens according to this embodiment has sufficient performance to correct aberration to realize high resolution.

(Eighteenth Embodiment)

FIG. 78 is a view showing the arrangement of a zoom lens in a seventeenth embodiment according to the present invention. As shown in FIG. 78, a zoom lens has a structure in which a first lens group 141, a second lens group 142, a third lens group 143, a fourth lens group 144, and a fifth lens group 145 are disposed from an object side (left side in FIG. 78) to an image plane side (right side in FIG. 78) in this order.

The first lens group 141 has a positive refracting power and is fixed with respect to the image plane in varying power and focusing. The second lens group 142 has a negative refracting power and varies power by moving along an optical axis. The third lens group 143 is composed of two lenses: a positive lens and a negative lens disposed from the object side in this order. The lenses of the third group have surfaces equal to each other in the sag amount, and this group has a positive refracting power as a whole.

The fourth lens group 144 is composed of two lenses as a cemented lens of a negative lens and a positive lens disposed from the object side in this order, and this group has a negative refracting power as a whole, and is fixed

with respect to the image plane in varying power and focusing. The fifth lens group 145 has a positive refracting power and moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power. When camera shake occurs, shake of an image is corrected by moving the third lens group 143 vertically with respect to the optical axis.

As described above, light beams entering the fifth lens group 145 can be lowered by combining the third lens group 143 having a positive refracting power as a whole and the fourth lens group 144 having a negative refracting power as a whole. Namely, since the lens diameter of the fourth group 144 can be decreased, a load on an actuator will be lighter in focusing.

The performance at shifting the lenses can be improved by applying at least one aspherical surface to any of the lenses of the third group 143.

Similar to the fourteenth embodiment, it is preferable for the zoom lens of this embodiment that the conditional expressions (8)-(16) are satisfied.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 67.

Table 67

Group	Surface	r	d	n	ν
1	1	35.171	0.90	1.80518	25.4
	2	18.474	5.25	1.60311	60.7
	3	−153.872	0.15		
	4	17.397	3.00	1.60311	60.7
	5	52.501	Variable		
2	6	52.501	0.60	1.78500	43.7
	7	5.178	2.97		
	8	−7.914	1.00	1.66547	55.2
	9	5.841	2.70	1.80518	25.4
	10	∞	Variable		
3	11	13.430	3.00	1.51450	63.1
	12	−13.430	0.60		
	13	−45.224	1.20	1.80518	25.4
	14	84.188	2.60		
4	15	−23.195	0.60	1.58913	61.2
	16	23.195	1.50	1.80518	25.4
	17	70.085	Variable		
5	18	−56.351	0.60	1.84666	23.9
	19	18.833	2.80	1.51633	64.1
	20	−13.089	0.10		
	21	11.081	2.85	1.51450	63.1
	22	−19.280	Variable		
6	23	∞	14.00	1.58913	61.2
	24	∞	2.80	1.51633	64.1
	25	∞	—		

The following Table 68 shows aspherical coefficients of the zoom lens in the present example.

Table 68

Surface	8	11	12	20
K	-8.93826×10^{-1}	-1.54989	-1.54989	-5.29341×10^{-1}
D	-1.30720×10^{-4}	-3.86132×10^{-5}	3.86132×10^{-5}	-8.85522×10^{-5}
E	-2.38410×10^{-5}	2.40598×10^{-7}	-2.40598×10^{-7}	-2.60439×10^{-7}

The following Table 69 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens. At the standard position, magnification of the second lens group

102 becomes −1 times in Table 69.

Table 69

	Wide-angle end	Standard position	Telephoto end
f	3.681	18.240	42.656
F/NO	1.655	1.874	2.067
2ω	58.529	12.076	5.120
d5 d10 d14 d19	0.600 17.503 5.200 1.000	11.710 6.393 2.321 3.879	14.974 3.129 5.200 1.000

The values of the expressions (8) to (14) are as follows.

rS1/rS9=0.79

|f3/f34|=0.62

BF/fw=3.58

f1/fw=7.00

|f2|/fw=1.26

f34/fw=8.83

f5/fw=3.23

FIGs. 79-81 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. As clearly shown in the aberrations of FIGs. 79-81, a zoom lens according to this embodiment has sufficient performance to correct aberration to realize high resolution.

(Nineteenth Embodiment)

FIG. 82 is a view showing the arrangement of a zoom lens in a nineteenth embodiment according to the present invention. As shown in FIG. 82, a zoom lens has a structure in which a first lens group 181, a second lens group 182, a third lens group 183, a fourth lens group 184, and a fifth lens group 185 are disposed from an object side (left side in FIG. 82) to an image plane side (right side in FIG. 82) in this order.

The first lens group 181 has a positive refracting power and is fixed with respect to the image plane in varying power and focusing. The second lens group 182 has a negative refracting power and varies power by moving along an optical axis. The third lens group 183 is composed of one lens

having a positive refracting power.

The fourth lens group 184 is composed of two lenses as a cemented lens of a negative lens and a positive lens disposed from the object side in this order and this group has a negative refracting power as a whole, and is fixed with respect to the image plane varying power and focusing. The fifth lens group 185 has a positive refracting power and moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power. When camera shake occurs, shake of an image is corrected by moving the third lens group 183 vertically with respect to the optical axis.

As a result, the tolerance can be eased by forming a shift lens group (the third lens group 183) with one lens.

The performance when shifting the lens can be improved by applying at least one aspherical surface to the lens of the third group 183.

Similar to the fourteenth embodiment, it is preferable for the zoom lens of this embodiment that the conditional expressions (8)-(16) are satisfied.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 70.

Table 70

Group	Surface	r	d	n	ν
1	1	35.243	0.90	1.80518	25.4
	2	18.353	5.25	1.60311	60.7
	3	−154.339	0.15		
	4	17.449	3.00	1.60311	60.7
	5	53.989	Variable		
2	6	53.989	0.70	1.78500	43.7
	7	5.142	2.97		
	8	−7.948	0.80	1.66547	55.2
	9	5.519	2.70	1.80518	25.4
	10	1291.253	Variable		
3	11	13.124	2.40	1.43425	95.0
	12	−23.353	2.70		
4	13	−45.406	0.60	1.58913	61.2
	14	24.428	1.50	1.80518	25.4
	15	36.015	Variable		
5	16	−69.769	0.60	1.84666	23.9
	17	18.397	2.70	1.51633	64.1
	18	−13.178	0.10		
	19	11.587	2.95	1.51450	63.1
	20	−21.551	Variable		
6	21	∞	14.00	1.58913	61.2
	22	∞	2.80	1.51633	64.1
	23	∞	—		

The following Table 71 shows aspherical coefficients of the zoom lens in the present example.

Table 71

Surface	8	11	12	19
K	-4.89985	-6.72168	$-1.37149 \times 10^{+1}$	-6.00589×10^{-1}
D	-1.08175×10^{-3}	3.03174×10^{-4}	8.68352×10^{-6}	-5.27645×10^{-5}
E	-1.06040×10^{-5}	-9.85138×10^{-7}	2.15192×10^{-6}	-3.20955×10^{-7}

The following Table 72 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens. At the standard position, magnification of the second lens group 182 becomes –1 times in Table 72.

Table 72

	Wide-angle end	Standard position	Telephoto end
f	3.690	18.643	42.802
F/NO	1.661	1.872	2.077
2ω	58.504	11.814	5.116
d5 d10 d14 d19	0.600 17.903 5.200 1.000	11.675 6.827 2.299 3.901	14.927 3.575 5.200 1.000

The values of the expressions (8) to (14) are as follows.

$rS1/rS9=1.02$ (eleventh plane)

$rS1/rS9=0.26$ (twelfth plane)

$|f3/f34|=0.60$

$BF/fw=3.60$

$f1/fw=6.98$

$|f2|/fw=1.25$

$f34/fw=8.93$

$f5/fw=3.36$

FIGs. 83-85 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. As clearly shown in the aberrations of FIGs. 83-85, a zoom lens according to this embodiment has sufficient performance to correct aberration to obtain high resolution of a zoom lens.

(Twentieth Embodiment)

FIG. 86 is a view showing the arrangement of a zoom lens in a nineteenth embodiment according to the present invention. As shown in FIG. 86, a zoom lens has a structure in which a first lens group 221, a second lens group 222, a third lens group 223, a fourth lens group 224, and a fifth lens group 225 are disposed from an object side (left side in FIG. 86) to an image plane side (right side in FIG. 86) in this order.

The first lens group 221 has a positive refracting power and is fixed with respect to the image plane in varying power and at focusing. The second lens group 222 has a negative refracting power and varies power by

moving along the optical axis. The third lens group 223 is composed of two lenses: a positive lens and a negative lens disposed from the object side in this order, and this group has a positive refracting power as a whole.

The fourth lens group 224 is composed of two lenses: a positive lens and a negative lens disposed from the object side in this order and this group has a negative refracting power as a whole, and is fixed with respect to the image plane in varying power and focusing.

The fifth lens group 225 has a positive refracting power and moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power. When camera shake occurs, shake of an image is corrected by moving the third lens group 223 vertically with respect to the optical axis.

The performance when shifting the lenses can be improved by applying at least one aspherical surface to any of the lenses of the third group 223.

Similar to the fourteenth embodiment, it is preferable for the zoom lens of this embodiment that the conditional expressions (8)-(16) are satisfied.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 73.

Table 73

Group	Surface	r	d	n	ν
	1	35.243	0.90	1.80518	25.4
	2	18.353	5.25	1.60311	60.7
	3	−154.339	0.15		
	4	17.449	3.00	1.60311	60.7
	5	53.989	Variable		
2	6	53.989	0.70	1.78500	43.7
	7	5.142	2.97		
	8	−7.948	0.80	1.66547	55.2
	9	5.519	2.70	1.80518	25.4
	10	1291.253	Variable		
3	11	13.385	2.45	1.51450	63.1
	12	−17.352	0.60		
	13	−120.265	1.00	1.84666	25.4
	14	68.318	2.70		
4	15	−18.144	1.50	1.58913	61.2
	16	−15.906	1.00	1.80518	25.4
	17	−22.792	1.00		
	19	39.750	Variable		
5	20	−47.899	0.60	1.84666	23.9
	21	23.192	2.70	1.51633	64.1
	22	−12.941	0.10		
	23	10.762	2.95	1.51450	63.1
	24	−21.804	Variable		
6	25	∞	14.00	1.58913	61.2
	26	∞	2.80	1.51633	64.1
	27	∞	—		

The following Table 74 shows aspherical coefficients of the zoom lens in the present example.

Table 74

Surface	8	11	12	23
K	−4.89985	−5.91060	−5.50770	-7.58012×10^{-1}
D	-1.08175×10^{-3}	1.96402×10^{-4}	-2.82483×10^{-5}	-5.38373×10^{-5}
E	-1.06040×10^{-5}	-1.63114×10^{-6}	3.84825×10^{-6}	-2.44675×10^{-7}

The following Table 75 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of the lens. At the standard position, magnification of the second lens group

222 becomes −1 times in Table 75.

Table 75

	Wide-angle end	Standard position	Telephoto end
f	3.685	17.981	42.743
F/NO	1.728	1.936	2.074
2ω	58.590	12.248	5.113
d5	0.600	11.675	14.927
d10	17.903	6.827	3.575
d14	5.200	2.360	5.200
d19	1.000	3.840	1.000

The values of the expressions (8) to (14) are as follows.

$rS1/rS9=1.05$

$rS1/rS9=0.46$

$|f3/f34|=0.62$

$BF/fw=3.58$

$f1/fw=6.99$

$|f2|/fw=1.25$

$f34/fw=8.79$

$f5/fw=3.25$

FIGs. 87-89 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. As clearly shown in the aberrations of FIGs. 87-89, a zoom lens according to this embodiment has sufficient performance to correct aberration to realize high resolution.

(Twenty-first Embodiment)

FIG. 90 is a view showing the arrangement of a zoom lens in a twenty-first embodiment according to the present invention. As shown in FIG. 90, a zoom lens has a structure in which a first lens group 261, a second lens group 262, a third lens group 263, a fourth lens group 264, and a fifth lens group 265 are disposed from an object side (left side in FIG. 90) to an image plane side (right side in FIG. 90) in this order.

The first lens group 261 has a positive refracting power and is fixed with respect to the image plane in varying power and focusing. The second

lens group 262 has a negative refracting power and varies power by moving along an optical axis. The third lens group 263 is composed of two lenses: a positive lens and a negative lens disposed from the object side in this order, and this group has a positive refracting power as a whole.

The fourth lens group 264 is composed of two lenses: a negative lens and a positive lens disposed from the object side in this order and this group has a negative refracting power as a whole, and is fixed with respect to the image plane in varying power and focusing. The fifth lens group 265 has a positive refracting power and moves along an optical axis so as to move an image and adjust the focus thereof at the same time in accordance with variable power. When camera shake occurs, shake of an image is corrected by moving the third lens group 263 vertically with respect to the optical axis.

The performance when shifting the lenses can be improved by applying at least one aspherical surface to any of the lenses of the third group 263.

Similar to the fourteenth embodiment, it is preferable for the zoom lens of this embodiment that the conditional expressions (8)-(16) are satisfied.

Specific examples of zoom lenses according to this embodiment are shown in the following Table 76.

Table 76

Group	Surface	r	d	n	ν
1	1	35.243	0.90	1.80518	25.4
	2	18.353	5.25	1.60311	60.7
	3	−154.339	0.15		
	4	17.449	3.00	1.60311	60.7
	5	53.989	Variable		
2	6	53.989	0.70	1.78500	43.7
	7	5.142	2.97		
	8	−7.948	0.80	1.66547	55.2
	9	5.519	2.70	1.80518	25.4
	10	1291.253	Variable		
3	11	13.379	2.45	1.51450	63.1
	12	−14.156	0.60		
	13	−61.508	1.00	1.80518	25.4
	14	64.122	2.70		
4	17	−28.305	1.00	1.51633	61.2
	18	24.977	1.60		
	19	19.641	1.50	1.80518	25.4
	20	25.463	Variable		
5	21	−54.314	0.60	1.84666	23.9
	22	24.366	2.70	1.51633	64.1
	23	−13.009	0.10		
	24	11.183	2.95	1.51450	63.1
	25	−21.825	Variable		
6	26	∞	14.00	1.58913	61.2
	27	∞	2.80	1.51633	64.1
	28	∞	—		

The following Table 77 shows aspherical coefficients of the zoom lens in the present embodiment.

Table 77

Surface	8	13	22
K	−4.89985	−8.46317	−1.14637
D	-1.08175×10^{-3}	1.00945×10^{-4}	-6.03706×10^{-5}
E	-1.06040×10^{-5}	-1.63114×10^{-6}	-8.33884×10^{-8}

The following Table 78 shows an air distance (mm) that is varied by zooming in the case where an object is positioned 2 m away from the tip end of

the lens. At the standard position, magnification of the second lens group 262 becomes –1 times in Table 78.

Table 78

	Wide-angle end	Standard position	Telephoto end
f	3. 684	18. 016	42. 724
F/NO	1. 676	1. 898	2. 073
2ω	58. 536	12. 215	5. 106
d5 d10 d14 d19	0. 600 17. 903 5. 200 1. 000	11. 675 6. 827 2. 343 3. 857	14. 927 3. 575 5. 200 1. 000

The values of the Expressions (8) to (14) are as follows.

rS1/rS9=0.93

rS1/rS9=0.63

|f3/f34|=0.61

BF/fw=3.59

f1/fw=6.99

|f2|/fw=1.25

f34/fw=8.94

f5/fw=3.26

FIGs. 91-93 illustrate various aberrations at a wide-angle end, at a standard position and at a telephoto end of the zoom lens. As clearly shown in the aberrations of FIGs. 91-93, a zoom lens according to this embodiment has sufficient performance to correct aberration to realize high resolution.

(Twenty-second Embodiment)

FIG. 94 is a view showing the arrangement of a video camera (three-plate-type video camera) in a twenty-first embodiment according to the present invention. As shown in FIG. 94, a video camera according to this embodiment comprises a zoom lens 301, a low-pass filter 302, prisms 303a-303c for color separation, imagers 304a-304c, a signal processing circuit 305, a view finder 306, a sensor 307 for detecting camera shake, and an actuator 308 for driving the lens. The zoom lens of the fifteenth embodiment (see FIG. 66)

is used for the zoom lens 301, and thus, a small and highly-qualified video camera having a function for correcting camera shake is realized.

In this embodiment, the zoom lens of FIG. 66 in the fifteenth embodiment is used. This zoom lens can be replaced by any of the zoom lenses shown in the sixteenth to twenty-first embodiments.

Although camera shake is corrected by shifting a lens group having a positive refracting power, similar effects can be obtained by shifting a lens group having a negative refracting power.

INDUSTRIAL APPLICABILITY

As mentioned above, the present invention provides a zoom lens having a function to correct camera shake, i.e., a function to optically correct shake of an image caused by camera shake, vibration etc. The zoom lens can be made small and compact with less deterioration in the aberration performance. Such a zoom lens can be used as a zoom lens for a video camera or for an electronic still camera.

Article 19

AMENDED CLAIMS

1. (Amended) A zoom lens, comprising: a first lens group having a positive refracting power and being fixed with respect to an image plane; a second lens group having a negative refracting power and varying power by moving along an optical axis; a third lens group having a positive refracting power, composed of two lenses of a positive lens and a negative lens that comprise at least one aspherical surface, and fixed with respect to the image plane; and a fourth lens group having a positive refracting power, comprising at least one aspherical surface and moving along an optical axis so as to keep the image plane varied by a shift of the second lens group and an object at a predetermined position from a reference surface,
the first, second, third and fourth lens groups being disposed from the object side in this order,
wherein the entire third lens group is moved vertically with respect to the optical axis so as to correct a movement of an image during camera shake; and a shifting amount Y of the third lens group at a focal length f of the entire system when correcting camera shake, a shifting amount Yt of the third lens group at a telephoto end, and a focal length ft of the telephoto end satisfy the following conditional expressions

$Yt>Y$; and

$(Y/Yt) / (f/ft)<1.5$.

2. (Cancelled)

3. (Cancelled)

4. (Cancelled)

5. (Cancelled)

6. (Cancelled)

7. (Cancelled)

8. (Cancelled)

9. A zoom lens according to claim 1, wherein a focal length f3 of the third lens group and a focal length fw of an entire system at a wide-angle end satisfy the following conditional expression

$2.0 < f3/fw < 4.0$.

10. A zoom lens according to claim 1, wherein a surface on the object side of a lens disposed closest to the object side in the third lens group is aspherical, and a local radius of curvature R10 in the vicinity of an optical axis and a local radius of curvature R11 in an outer peripheral portion satisfy the following conditional expression

$1.05 < R11/R10 < 2.5$.

11. A zoom lens according to claim 1, wherein a surface on the object side of a lens disposed closest to the object side in the fourth lens group is aspherical, and a local radius of curvature R20 in the vicinity of an optical axis and a local radius of curvature R21 in an outer peripheral portion satisfy the following conditional expression

$1.05 < R21/R20 < 2.0$.

12. (Amended) A video camera provided with a zoom lens of any one of claims 1, 9, 10 or 11.

13. (Amended) A zoom lens, comprising: a first lens group having a positive refracting power and being fixed with respect to an image plane; a second lens group having a negative refracting power and varying power by moving along an optical axis; a third lens group having a positive refracting power and being fixed with respect to the image plane; a fourth lens group having a negative refracting power and being fixed with respect to the image plane; and a fifth lens group having a positive refracting power and moving along an optical axis so as to keep the image plane varied by a shift of the second lens group and an object at a predetermined position from a reference surface,

the first, second, third, fourth and fifth lens groups being disposed from the object side in this order,

wherein the third lens group is moved vertically with respect to the optical axis so as to correct movement of an image during camera shake.

14. (Amended) A zoom lens according to claim 13, wherein the third lens group is composed of two lenses: one positive lens and one negative lens.

15. (Cancelled)

16. A zoom lens according to claim 13, wherein the fourth lens group is composed of two lenses separated from each other: one positive lens and one negative lens.

17. A zoom lens according to claim 13, wherein the fourth lens group is composed of two cemented lenses: one positive lens and one negative lens.

18. (Cancelled)

19. A zoom lens according to claim 13, wherein the third lens group and the fourth lens group are composed two lenses respectively, and Abbe's number ν31 of one lens of the third group, Abbe's number ν32 of the remaining lens of the third group, Abbe's number ν41 of one lens of the fourth group and Abbe's number ν42 of the remaining lens of the fourth group satisfy the following conditional expressions

$$|\nu31-\nu32|>25.$$

$$|\nu41-\nu42|>25$$

20. (Amended) A zoom lens according to claim 13, wherein the third is composed of two lenses: one lens having a positive refracting power and one lens having a negative refracting power being disposed separately from the object side in this order, and the lenses have sag amounts equal in the object side and in the image side.

21. (Amended) A zoom lens according to claim 13, wherein the third lens group is composed of three lenses comprising at least one positive lens and at least one negative lens.

22. (Amended) A zoom lens according to claim 13, wherein the third lens group is composed of one lens.

23. (Amended) A zoom lens according to claim 13, wherein the third lens

group comprises at least one aspherical surface.

24. (Amended) A zoom lens according to claim 13, wherein the third lens group comprises a convex lens having an aspherical surface when viewed from the object side, and a local radius of curvature rS1 for a diameter occupying 10% of a lens effective diameter and a local radius of curvature rS9 for a diameter occupying 90% of a lens effective diameter satisfy the following conditional expression

$$0.01<rS1/rS9<2.00.$$

25. A zoom lens according to claim 13, wherein a focal length f3 of the third lens group and a focal length f34 of a composite focal length of the third and fourth lens group satisfy the following conditional expression

$$0.40<|f3/f34|<0.85.$$

26. A zoom lens according to claim 13, wherein a focal length fw of an entire system at the wide-angle end and a distance BF between the final surface of the lens and the image plane in the air satisfy the following conditional expression

$$0<BF<fw<5.0.$$

27. A zoom lens according to claim 13, wherein a focal length fw of an entire system at the wide-angle end, focal length fi (i=1-5) of the i-th lens group, and a composite focal length f34 of the third and fourth lens groups satisfy the following expressions

$$5.0<f1/fw<8.0$$
$$0.5<|f2|/fw<1.6$$
$$4.0<f34/fw<9.5$$
$$2.0<f5/fw<5.0.$$

28. A zoom lens according to claim 13, wherein a shifting amount Y of the third lens group at a focal length f of an entire system when correcting camera shake, a shifting amount Yt of the third lens group at a telephoto end and a focal length ft of the telephoto end satisfy the following conditional expressions

$$Yt>Y;$$
$$(Y/Yt)/(f/ft)<1.5.$$

29. (Amended) A video camera provided with a zoom lens of any one of claims 13, 14, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27 or 28.

30. (New) A zoom lens, comprising: a first lens group having a positive refracting power and being fixed with respect to an image plane; a second lens group having a negative refracting power and varying power by moving along an optical axis; a third lens group having a positive refracting power, comprising at least one aspherical surface, being composed of three lenses that comprise at least one positive lens and at least one negative lens, and fixed with respect to the image plane; and a fourth lens group having a positive refracting power, comprising at least one aspherical surface and moving along an optical axis so as to keep the image plane varied by a shift of the second lens group and an object at a predetermined position from a reference surface,
the first, second, third and fourth lens groups being disposed from the object side in this order,
wherein the entire third lens group is moved vertically with respect to the optical axis so as to correct a movement of an image during camera shake; and a shifting amount Y of the third lens group at a focal length f of an entire system when correcting camera shake, a shifting amount Yt of the third lens group at a telephoto end, and a focal length ft of the telephoto end satisfy the following conditional expressions

$$Yt>Y; \text{ and}$$
$$(Y/Yt) / (f/ft)<1.5.$$

31. (New) A zoom lens according to claim 30, wherein the third lens group comprises a positive lens, and a cemented lens of a positive lens and a negative lens.

32. (New) A zoom lens according to claim 30, wherein a focal length f3 of the third lens group and a focal length fw of an entire system at a wide-angle end satisfy the following conditional expression

$$2.0 < f3/fw < 4.0.$$

33. (New) A zoom lens according to claim 30, wherein a surface on the object side of a lens disposed closest to the object side in the third lens group is

is aspherical, and a local radius of curvature R10 in the vicinity of an optical axis and a local radius of curvature R11 in an outer peripheral portion satisfy the following conditional expression

$$1.05 < R11/R10 < 2.5.$$

34. (New) A zoom lens according to claim 30, wherein a surface on the object side of a lens disposed closest to the object side in the fourth lens group is aspherical, and a local radius of curvature R20 in the vicinity of an optical axis and a local radius of curvature R21 in an outer peripheral portion satisfy the following conditional expression

$$1.05 < R21/R20 < 2.0.$$

35. (New) A video camera provided with a zoom lens of any one of claims 30 to 34.

ABSTRACT

Provided from the object side are a first lens group (11) having a positive refracting power and fixed to the image plane, a second lens group (12) having a negative refracting power and a magnification varying action exhibited when moving along the optical axis, a third lens group (13) fixed to the image plane and having a positive refracting power, and a fourth lens group (14) movable along the optical axis so as to maintain the image plane moving with the movements of the second lens group (12) and of the object in a fixed position from a reference plane. Hence the movement of the image due to camera shake is corrected by moving the whole third lens group (13) vertically to the optical axis. The size is reduced and the aberrations are small because the whole groups whose optical performance is united are decentered.

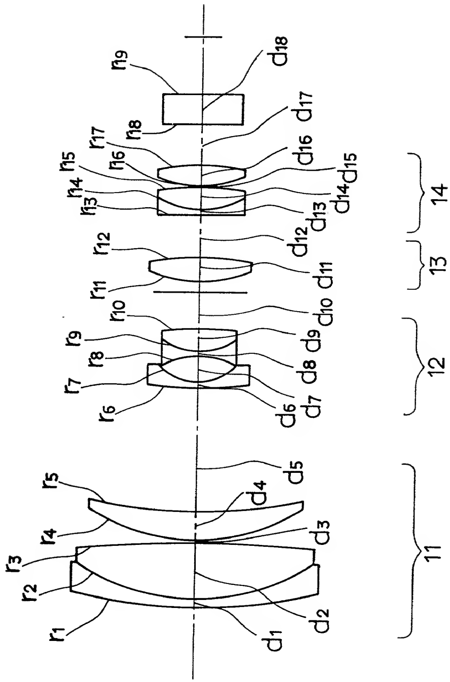

r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r18
r19
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
11
12
13
14

FIG. 1

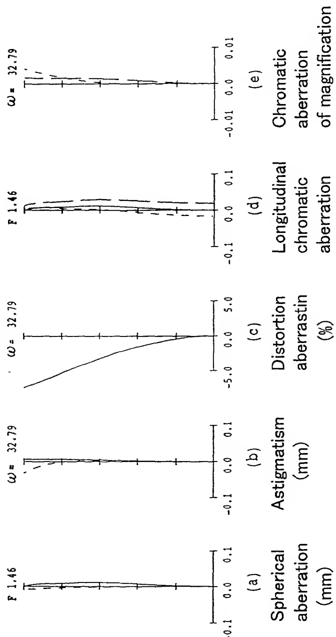

F 1.46
-0.1
0.0
0.1
(a)
Spherical aberration (mm)
ω= 32.79
-0.1
0.0
0.1
(b)
Astigmatism (mm)
ω= 32.79
-5.0
0.0
5.0
(c)
Distortion aberrastin (%)
F 1.46
-0.1
0.0
0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 32.79
-0.01
0.0
0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 2

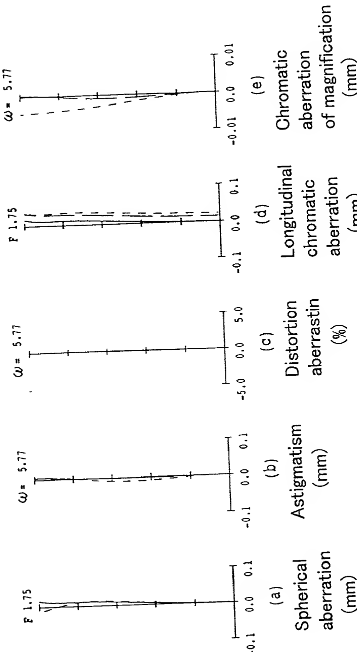

F 1.75
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω= 5.77
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω= 5.77
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.75
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 5.77
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 3

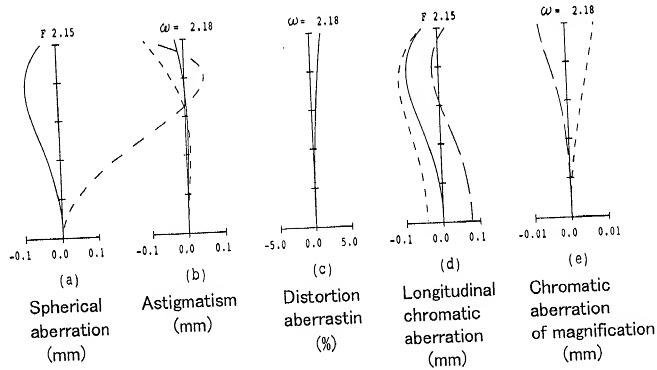


FIG. 4

09/701754

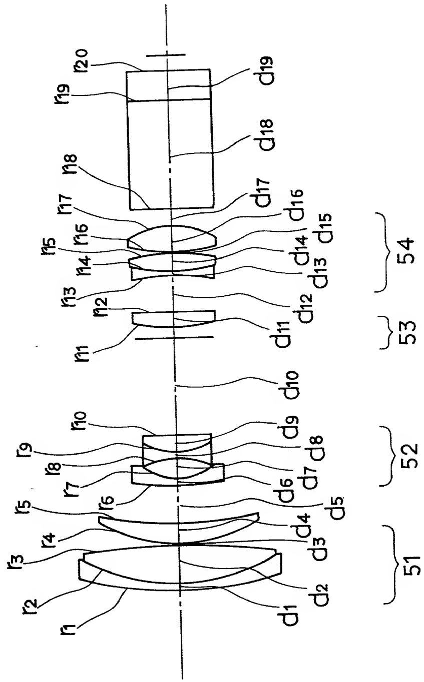
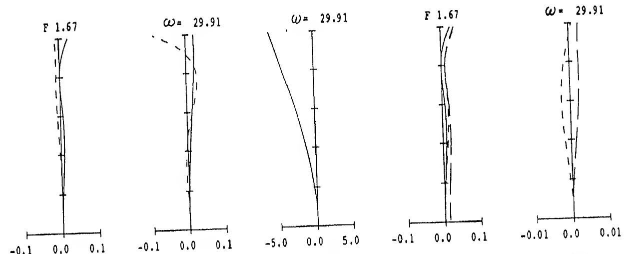

r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r18
r19
r20
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
d19
51
52
53
54

FIG. 5



(a) Spherical aberration (mm)

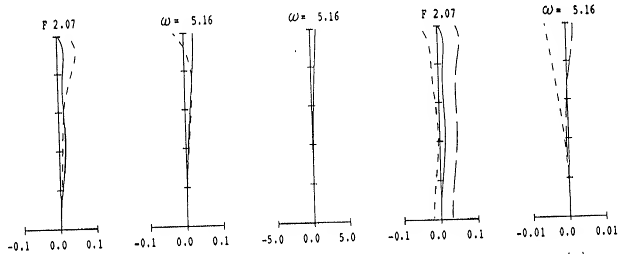
(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 6



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 7

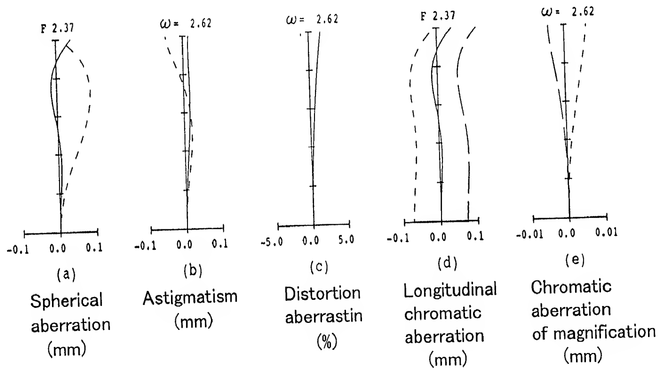

F 2.37
ω= 2.62
ω= 2.62
F 2.37
ω= 2.62
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.01 0.0 0.01
(a)
Spherical aberration (mm)
(b)
Astigmatism (mm)
(c)
Distortion aberrastin (%)
(d)
Longitudinal chromatic aberration (mm)
(e)
Chromatic aberration of magnification (mm)

FIG. 8

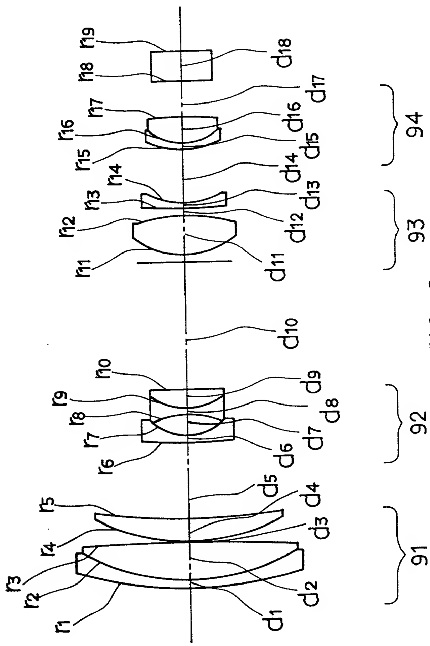

r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r18
r19
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
91
92
93
94

FIG. 9

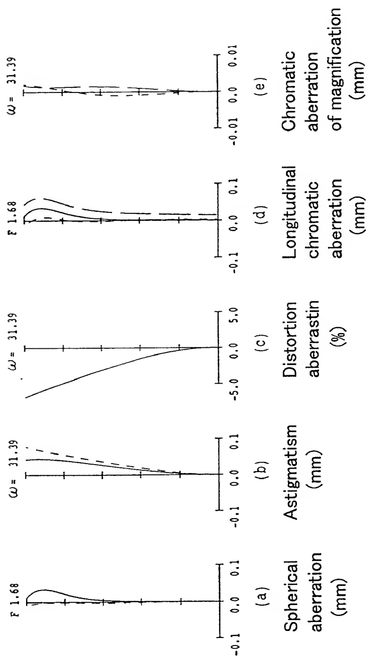
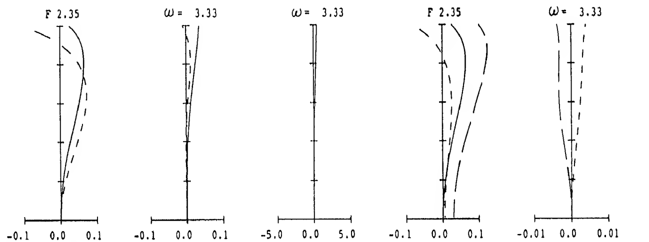

F 1.68
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω = 31.39
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω = 31.39
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.68
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω = 31.39
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 10



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 11

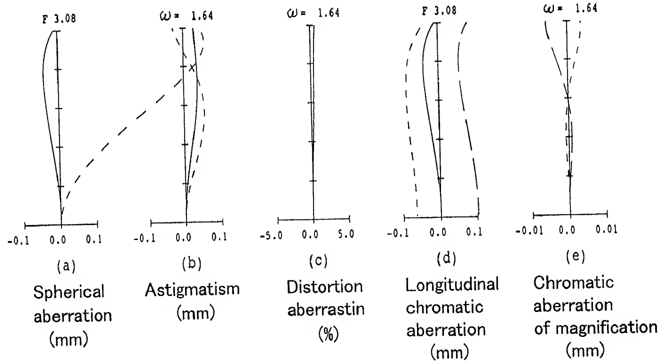

F 3.08
ω = 1.64
ω = 1.64
F 3.08
ω = 1.64
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.01 0.0 0.01
(a)
Spherical aberration (mm)
(b)
Astigmatism (mm)
(c)
Distortion aberrastin (%)
(d)
Longitudinal chromatic aberration (mm)
(e)
Chromatic aberration of magnification (mm)

FIG. 12

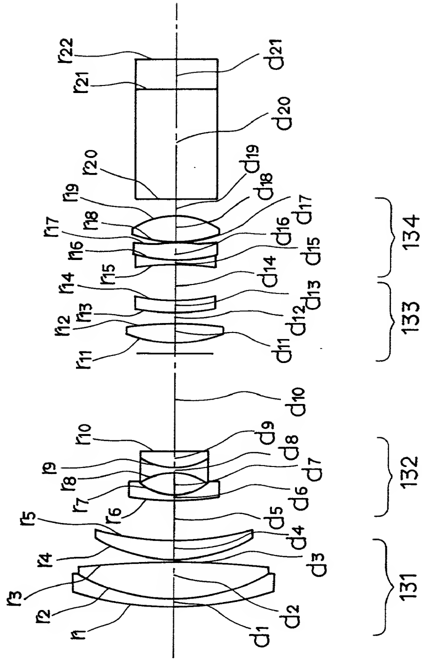

r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r18
r19
r20
r21
r22
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
d19
d20
d21
131
132
133
134

FIG. 13

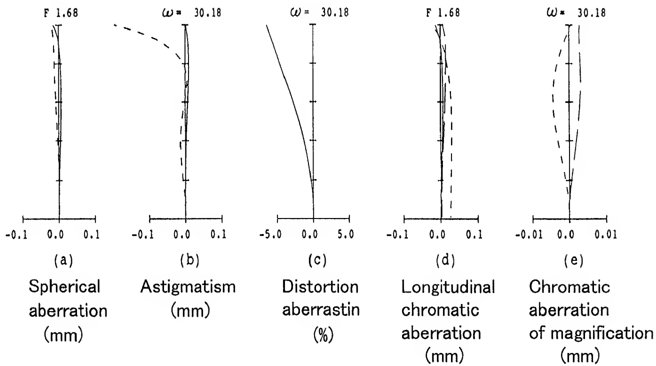
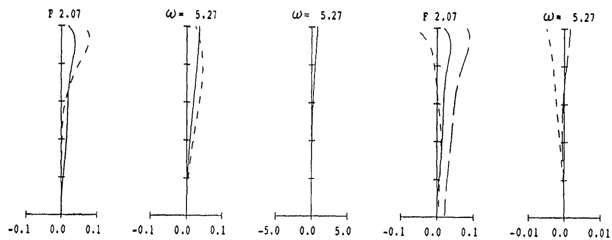

F 1.68
ω= 30.18
ω= 30.18
F 1.68
ω= 30.18
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.01 0.0 0.01
(a)
Spherical aberration (mm)
(b)
Astigmatism (mm)
(c)
Distortion aberrastin (%)
(d)
Longitudinal chromatic aberration (mm)
(e)
Chromatic aberration of magnification (mm)

FIG. 14



(a) Spherical aberration (mm)

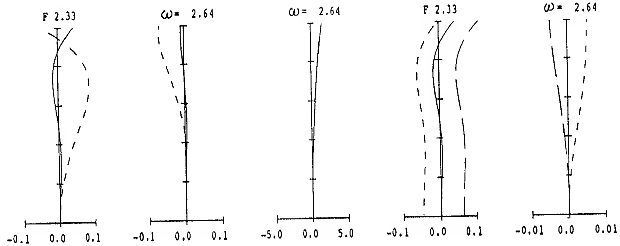
(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 15



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 16

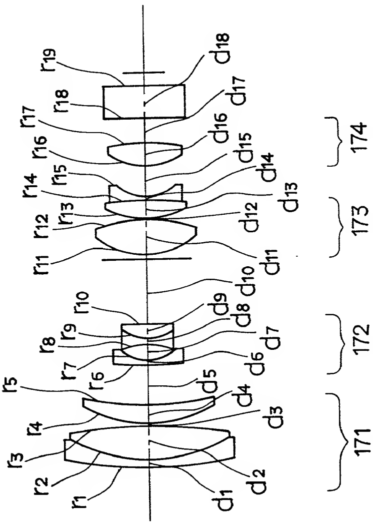

r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r18
r19
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
171
172
173
174

FIG. 17

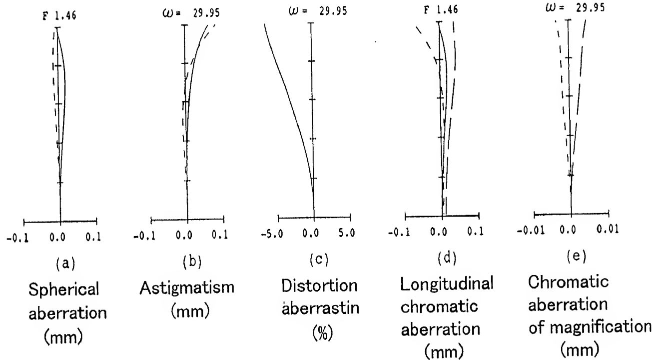

F 1.46
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω= 29.95
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω= 29.95
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.46
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 29.95
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 18

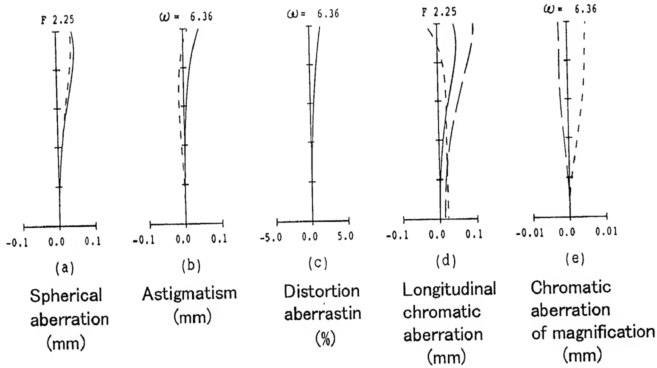
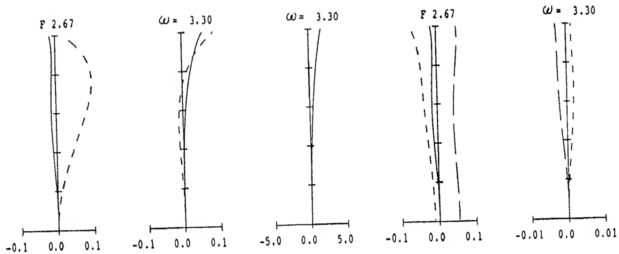

F 2.25
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω = 6.36
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω = 6.36
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 2.25
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω = 6.36
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 19



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 20

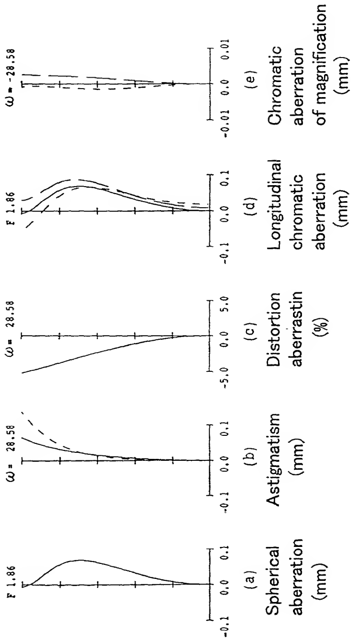

F 1.86
-0.1 0.0 0.1
(a) Spherical aberration (mm)
ω = 28.58
-0.1 0.0 0.1
(b) Astigmatism (mm)
ω = 28.58
-5.0 0.0 5.0
(c) Distortion aberrastin (%)
F 1.86
-0.1 0.0 0.1
(d) Longitudinal chromatic aberration (mm)
ω = -28.58
-0.01 0.0 0.01
(e) Chromatic aberration of magnification (mm)

FIG. 21

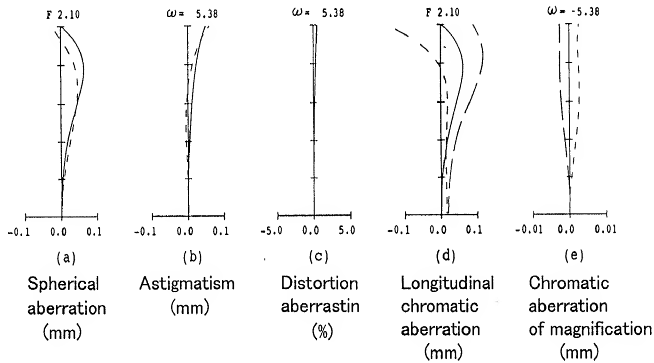

F 2.10
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω= 5.38
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω= 5.38
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 2.10
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω= -5.38
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 22

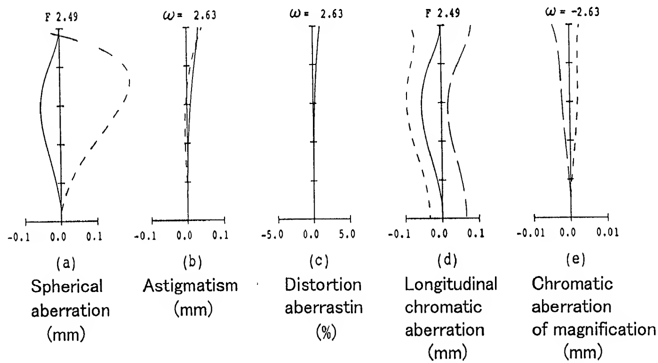
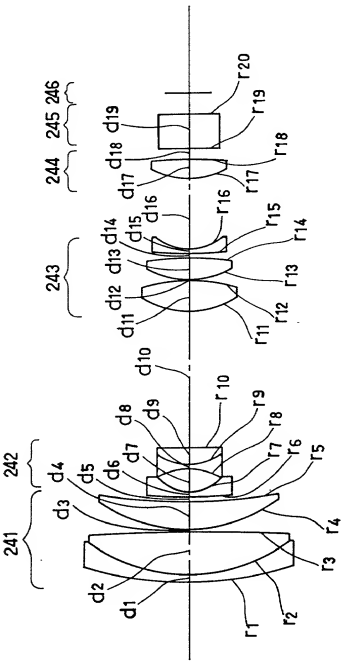

F 2.49
ω = 2.63
ω = 2.63
F 2.49
ω = -2.63
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.01 0.0 0.01
(a) Spherical aberration (mm)
(b) Astigmatism (mm)
(c) Distortion aberrastin (%)
(d) Longitudinal chromatic aberration (mm)
(e) Chromatic aberration of magnification (mm)

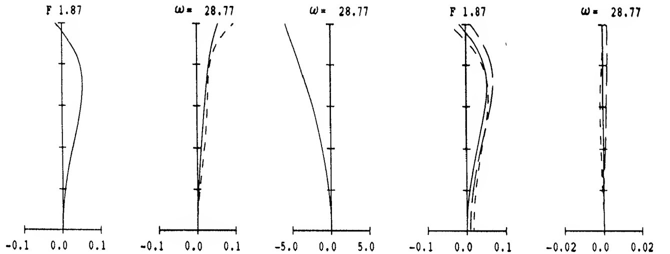
FIG. 23



241
242
243
244
245
246
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
d19
r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r18
r19
r20

FIG. 24

09/701754



(a) Spherical aberration (mm)

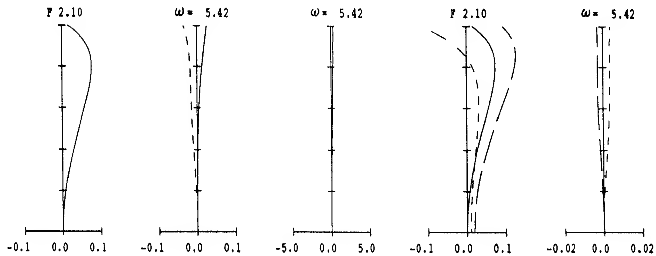
(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 25



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 26

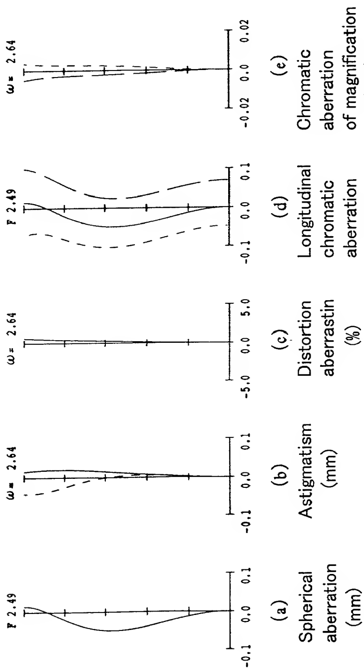

F 2.49
-0.1
0.0
0.1
(a)
Spherical aberration (mm)
ω= 2.64
-0.1
0.0
0.1
(b)
Astigmatism (mm)
ω= 2.64
-5.0
0.0
5.0
(c)
Distortion aberrastin (%)
F 2.49
-0.1
0.0
0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 2.64
-0.02
0.0
0.02
(e)
Chromatic aberration of magnification (mm)

FIG. 27

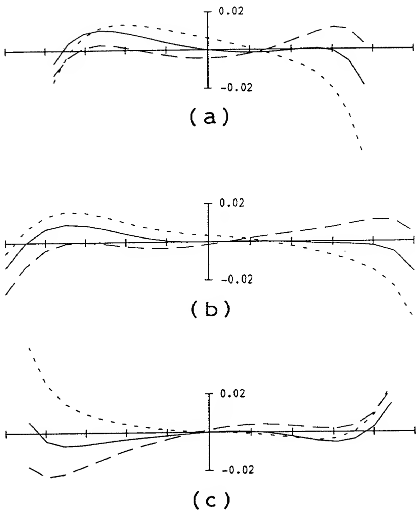


FIG. 28

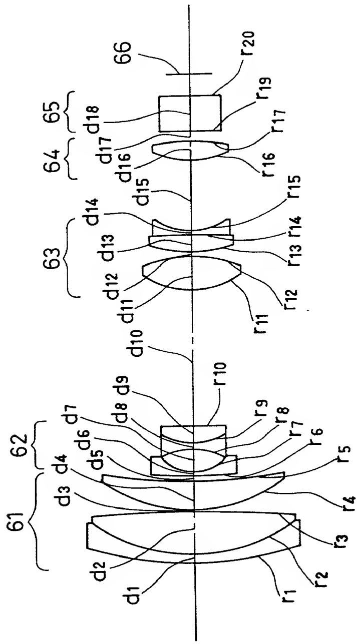

61
62
63
64
65
66
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r19
r20

FIG. 29

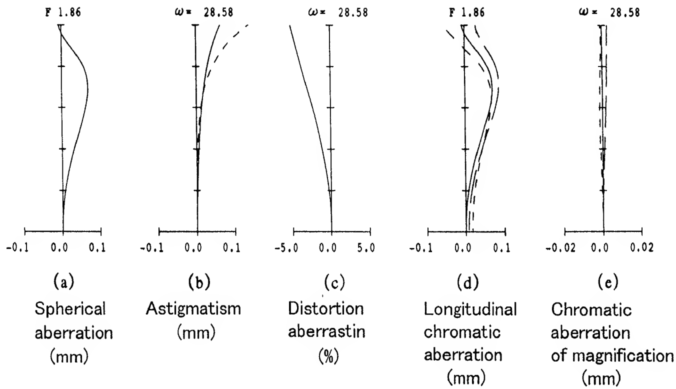
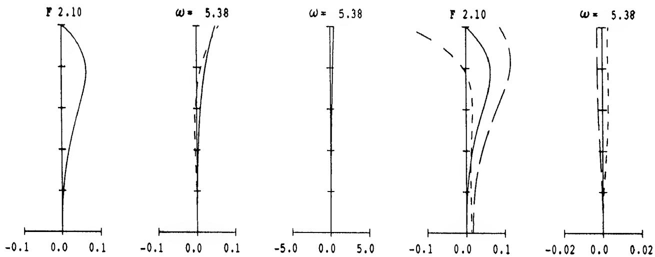

F 1.86
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω= 28.58
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω= 28.58
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.86
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 28.58
-0.02 0.0 0.02
(e)
Chromatic aberration of magnification (mm)

FIG. 30



(a) Spherical aberration (mm)

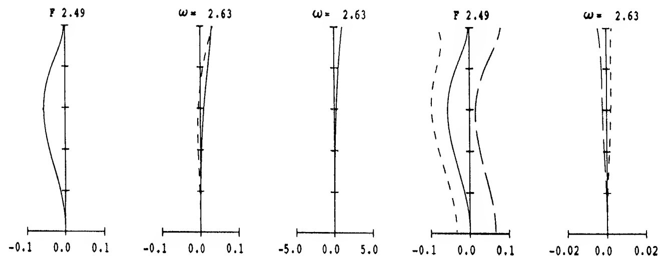
(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 31



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 32

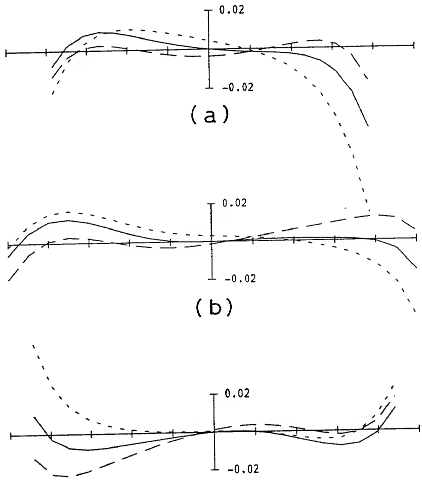


FIG. 33

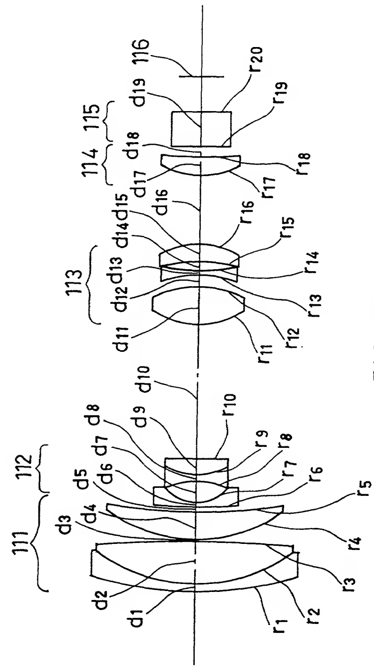

111
112
113
114
115
116
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
d19
r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r18
r19
r20

FIG. 34

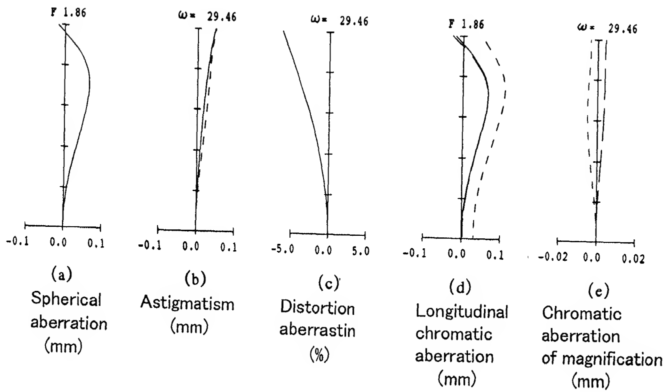
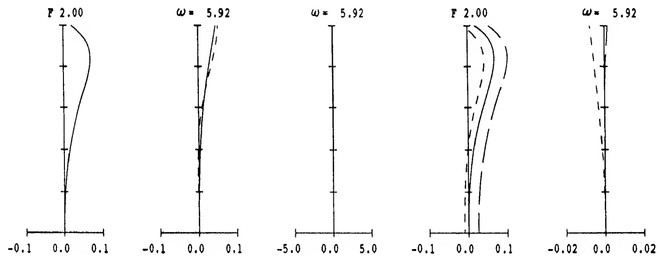

F 1.86
-0.1
0.0
0.1
(a)
Spherical aberration (mm)
ω= 29.46
-0.1
0.0
0.1
(b)
Astigmatism (mm)
ω= 29.46
-5.0
0.0
5.0
(c)
Distortion aberrastin (%)
F 1.86
-0.1
0.0
0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 29.46
-0.02
0.0
0.02
(e)
Chromatic aberration of magnification (mm)

FIG. 35



(a) Spherical aberration (mm)

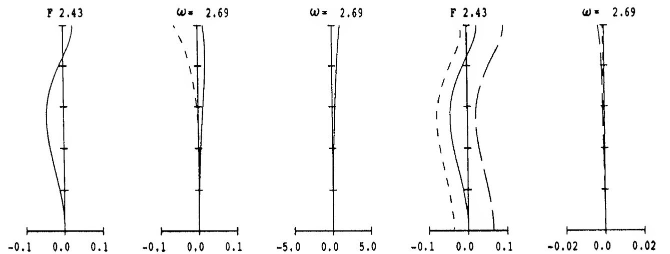
(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 36



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 37

09/701754

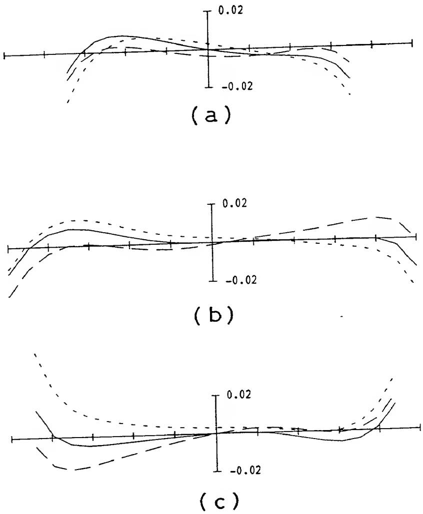


FIG. 38

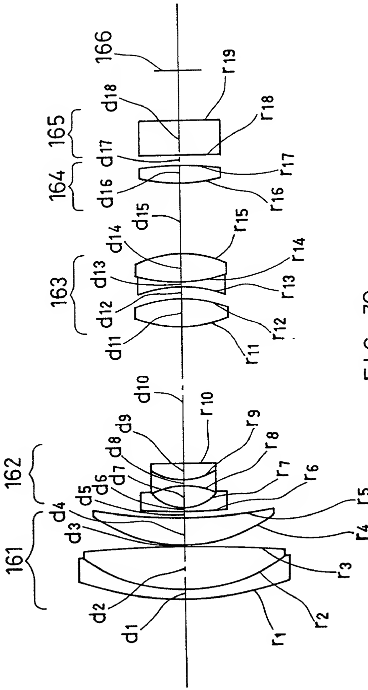
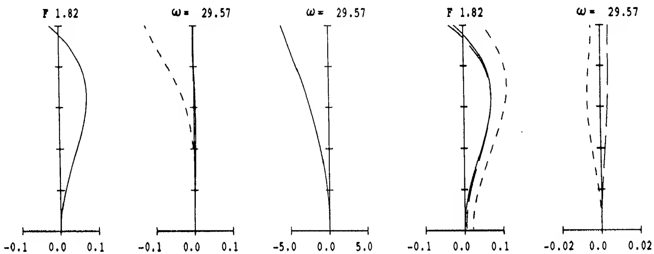

161
162
163
164
165
166
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r18
r19

FIG. 39



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 40

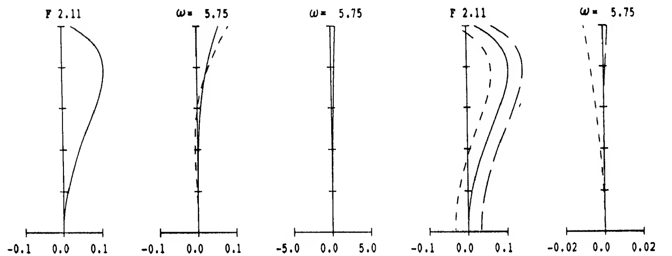

F 2.11
ω= 5.75
ω= 5.75
F 2.11
ω= 5.75
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.02 0.0 0.02
(a) Spherical aberration (mm)
(b) Astigmatism (mm)
(c) Distortion aberrastin (%)
(d) Longitudinal chromatic aberration (mm)
(e) Chromatic aberration of magnification (mm)

FIG. 41

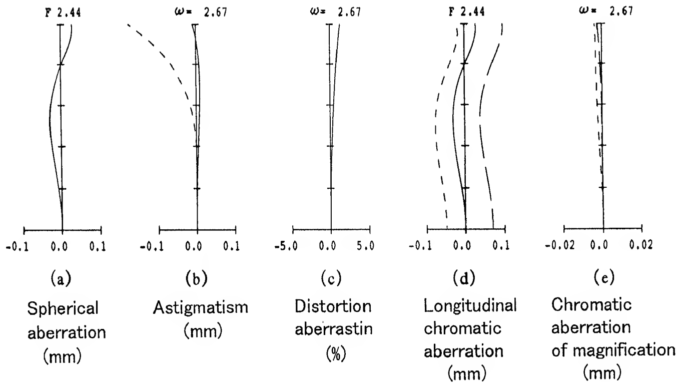

F 2.44
ω= 2.67
ω= 2.67
F 2.44
ω= 2.67
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.02 0.0 0.02
(a)
Spherical aberration (mm)
(b)
Astigmatism (mm)
(c)
Distortion aberrastin (%)
(d)
Longitudinal chromatic aberration (mm)
(e)
Chromatic aberration of magnification (mm)

FIG. 42

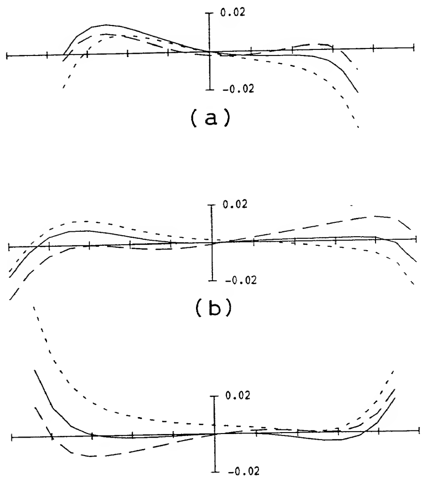


FIG. 43

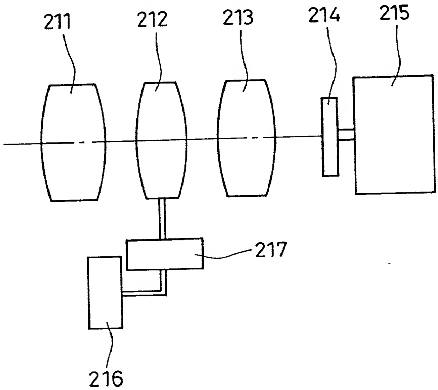


FIG . 44

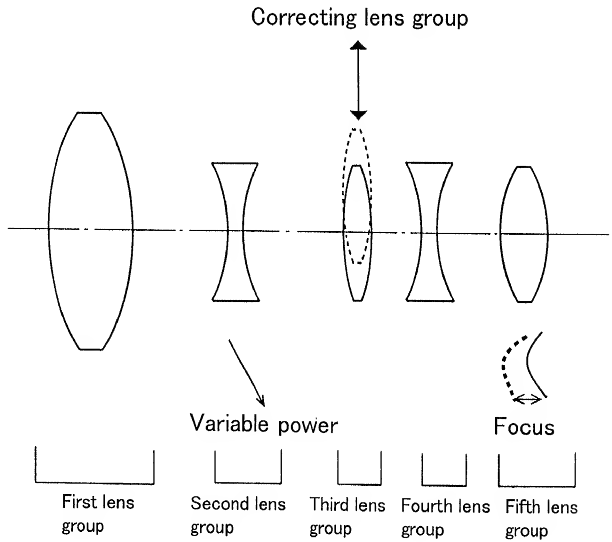

Correcting lens group
Variable power
Focus
First lens group
Second lens group
Third lens group
Fourth lens group
Fifth lens group

FIG. 45

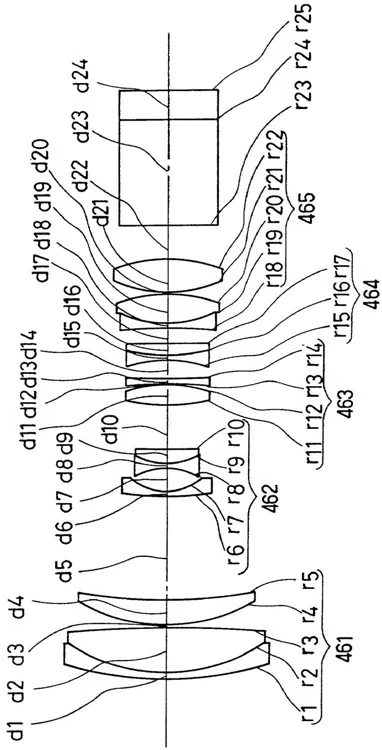

d1 d2 d3 d4 d5 d6 d7 d8 d9 d10 d11 d12 d13 d14 d15 d16 d17 d18 d19 d20 d21 d22 d23 d24
r1 r2 r3 r4 r5 r6 r7 r8 r9 r10 r11 r12 r13 r14 r15 r16 r17 r18 r19 r20 r21 r22 r23 r24 r25
461
462
463
464
465

FIG. 46

09/701754

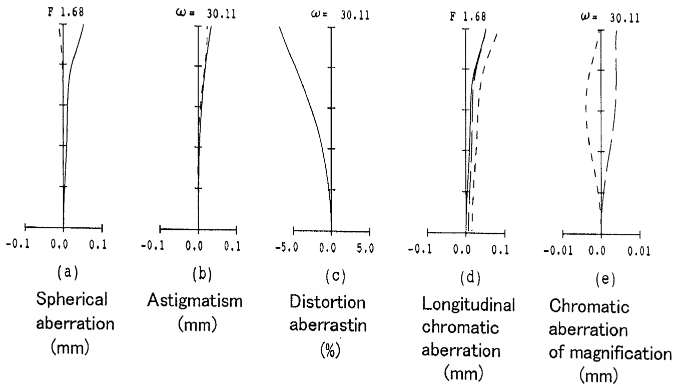
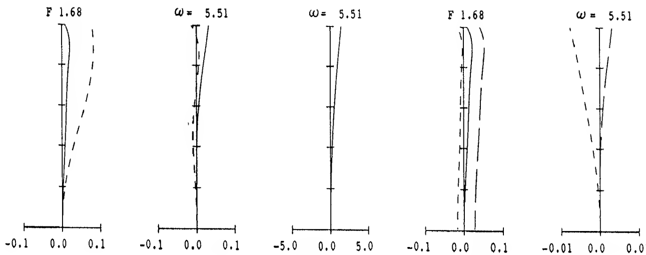


FIG. 47



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 48

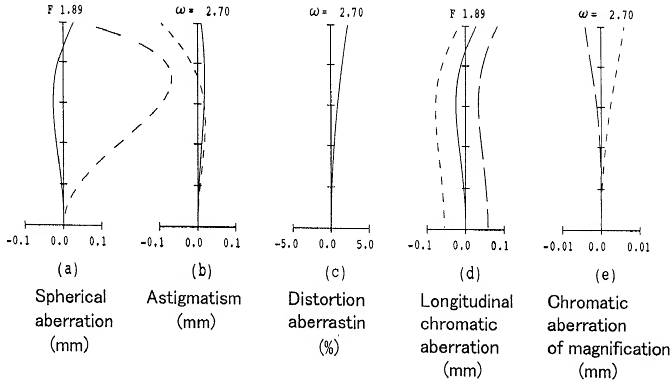
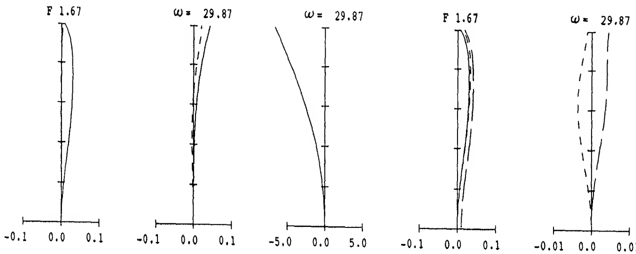

F 1.89
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω = 2.70
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω = 2.70
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.89
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω = 2.70
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 49



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 50

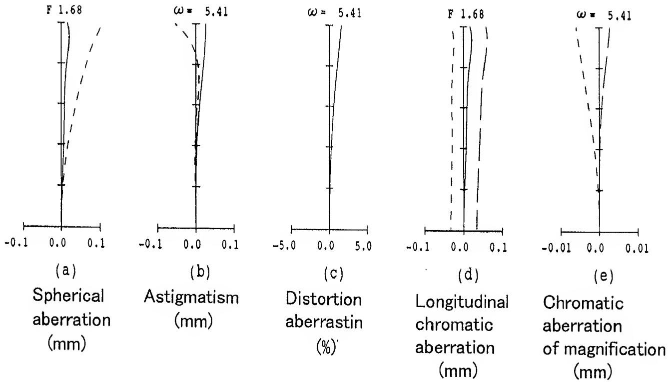
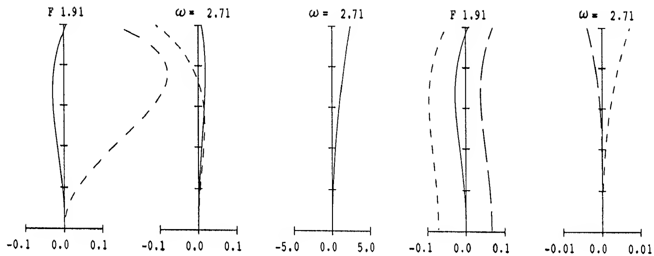

F 1.68
-0.1
0.0
0.1
(a)
Spherical aberration (mm)
ω = 5.41
-0.1
0.0
0.1
(b)
Astigmatism (mm)
ω = 5.41
-5.0
0.0
5.0
(c)
Distortion aberrastin (%)
F 1.68
-0.1
0.0
0.1
(d)
Longitudinal chromatic aberration (mm)
ω = 5.41
-0.01
0.0
0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 51



(a) Spherical aberration (mm)

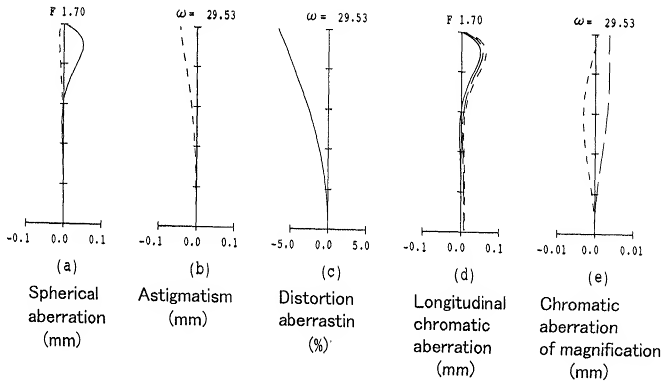
(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 52



F 1.70
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω = 29.53
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω = 29.53
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.70
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω = 29.53
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 53

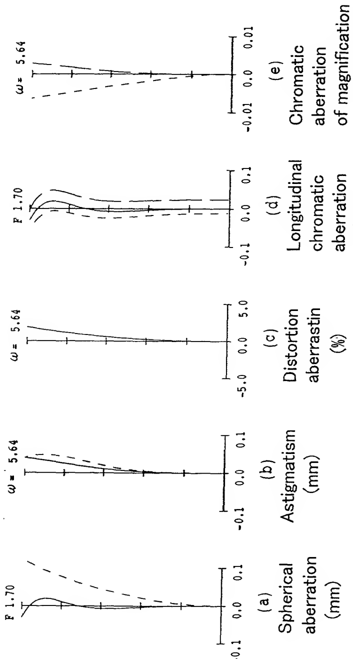

F 1.70
-0.1 0.0 0.1
(a)
Spherical aberration
(mm)
ω= 5.64
-0.1 0.0 0.1
(b)
Astigmatism
(mm)
ω= 5.64
-5.0 0.0 5.0
(c)
Distortion aberrastin
(%)
F 1.70
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration
(mm)
ω= 5.64
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification
(mm)

FIG. 54

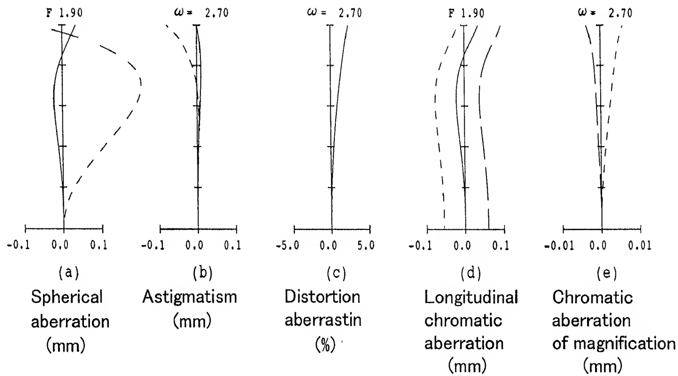

F 1.90
ω = 2.70
ω = 2.70
F 1.90
ω = 2.70
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.01 0.0 0.01
(a)
Spherical aberration (mm)
(b)
Astigmatism (mm)
(c)
Distortion aberrastin (%)
(d)
Longitudinal chromatic aberration (mm)
(e)
Chromatic aberration of magnification (mm)

FIG. 55

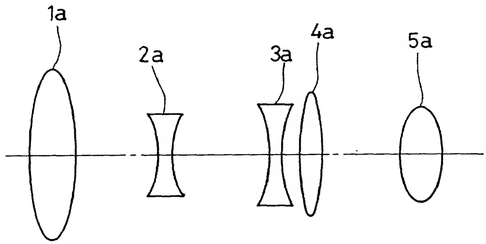


FIG. 56

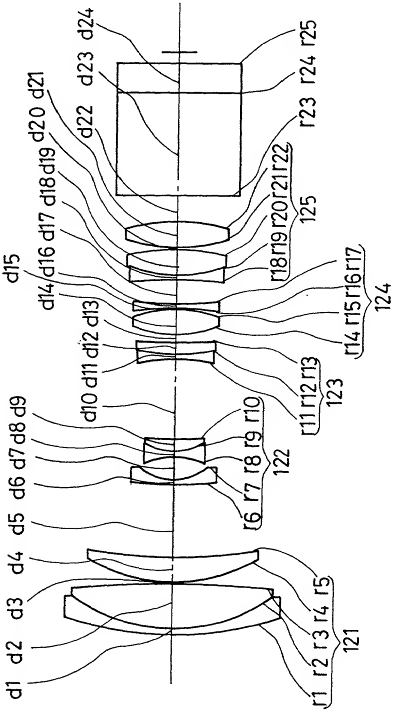

d1 d2 d3 d4 d5 d6 d7 d8 d9 d10 d11 d12 d13 d14 d15 d16 d17 d18 d19 d20 d21 d22 d23 d24
r1 r2 r3 r4 r5
121
r6 r7 r8 r9 r10
122
r11 r12 r13
123
r14 r15 r16 r17
124
r18 r19 r20 r21 r22
125
r23 r24 r25

FIG. 57

09/701754

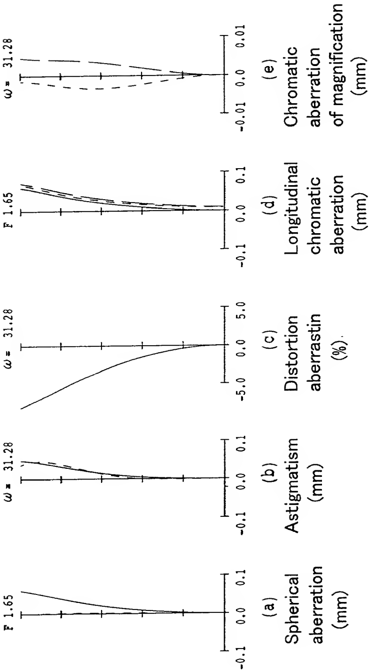


FIG. 58

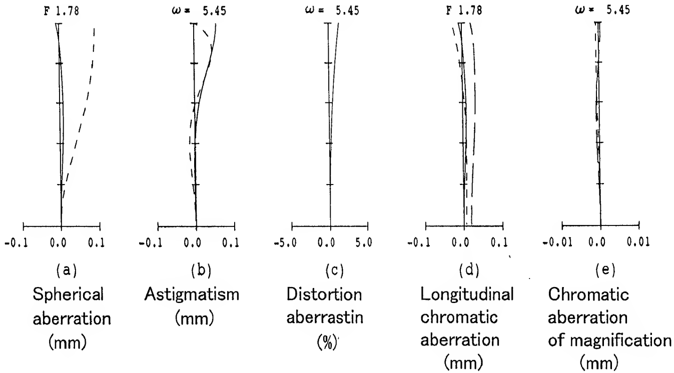

F 1.78
ω = 5.45
ω = 5.45
F 1.78
ω = 5.45
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.01 0.0 0.01
(a)
Spherical aberration (mm)
(b)
Astigmatism (mm)
(c)
Distortion aberrastin (%)
(d)
Longitudinal chromatic aberration (mm)
(e)
Chromatic aberration of magnification (mm)

FIG. 59

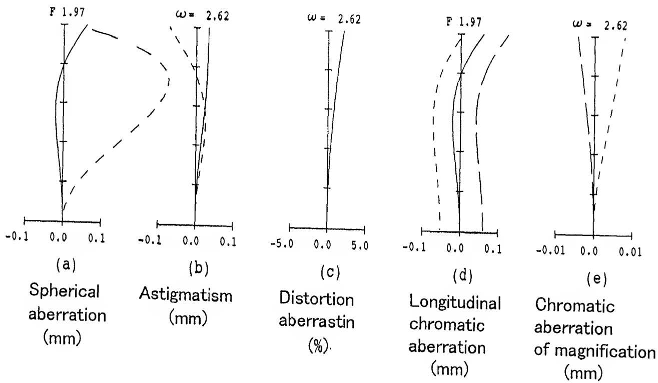

F 1.97
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω= 2.62
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω= 2.62
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.97
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 2.62
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 60

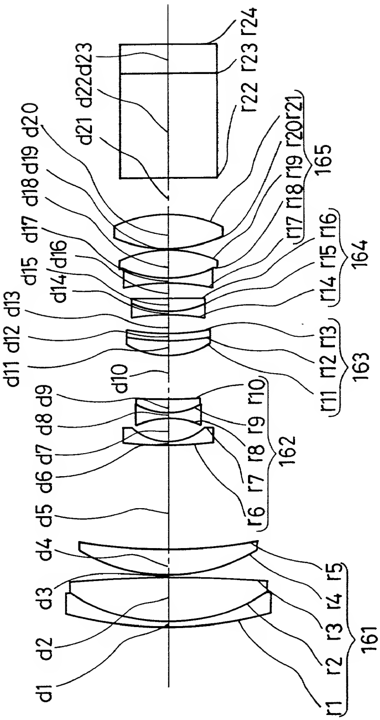
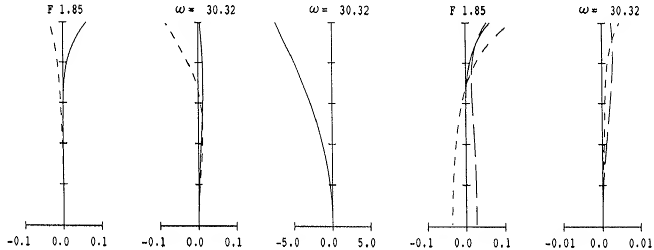

d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
d19
d20
d21
d22
d23
r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r18
r19
r20
r21
r22
r23
r24
161
162
163
164
165

FIG. 61



(a) Spherical aberration (mm)

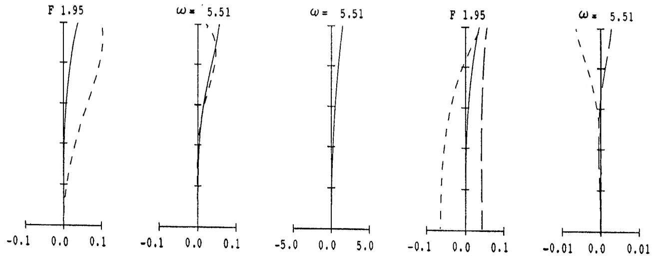
(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 62



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 63

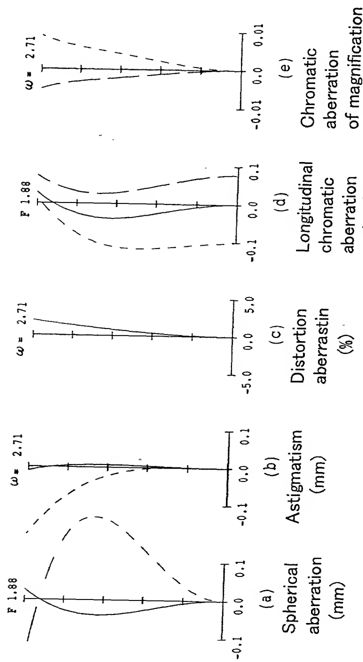

F 1.88
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω = 2.71
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω = 2.71
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.88
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω = 2.71
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 64

09/701754

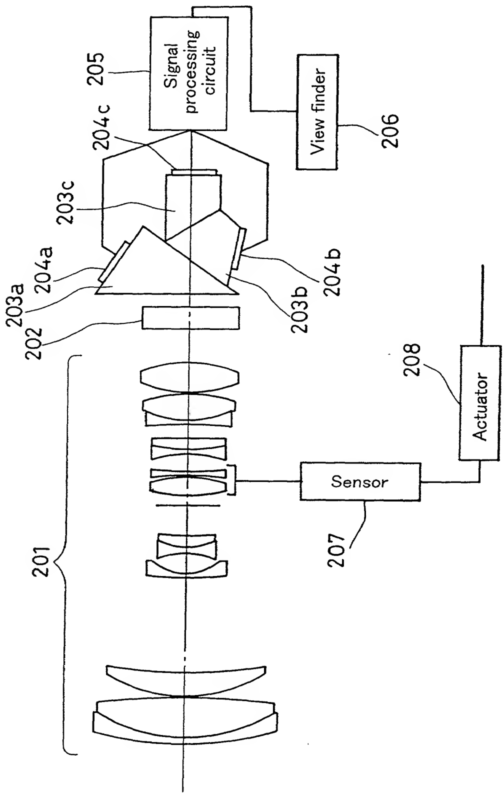


FIG. 65

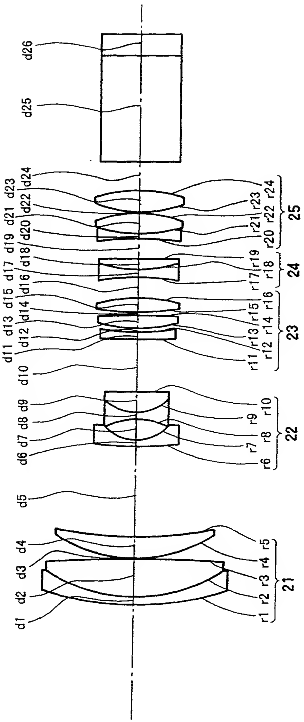
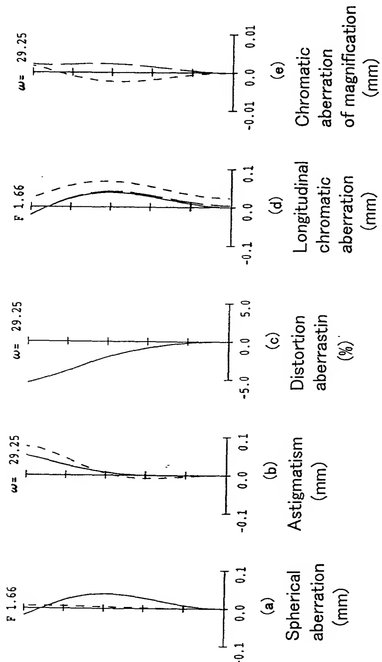

d1 d2 d3 d4 d5 d6 d7 d8 d9 d10 d11 d12 d13 d14 d15 d16 d17 d18 d19 d20 d21 d22 d23 d24 d25 d26
r1 r2 r3 r4 r5 r6 r7 r8 r9 r10 r11 r12 r13 r14 r15 r16 r17 r18 r19 r20 r21 r22 r23 r24
21
22
23
24
25

FIG. 66



F 1.66
-0.1
0.0
0.1
(a)
Spherical aberration (mm)
ω= 29.25
-0.1
0.0
0.1
(b)
Astigmatism (mm)
ω= 29.25
-5.0
0.0
5.0
(c)
Distortion aberrastin (%)
F 1.66
-0.1
0.0
0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 29.25
-0.01
0.0
0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 67

09/701754

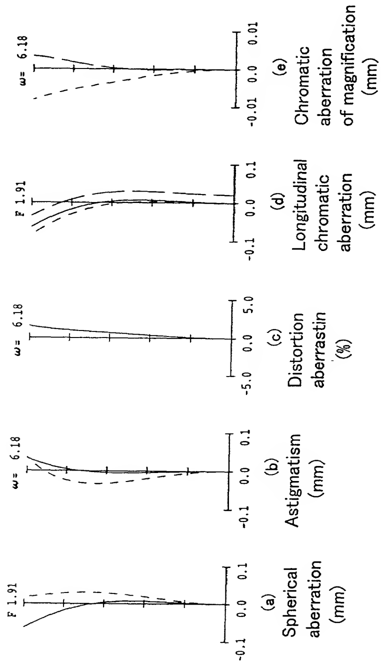
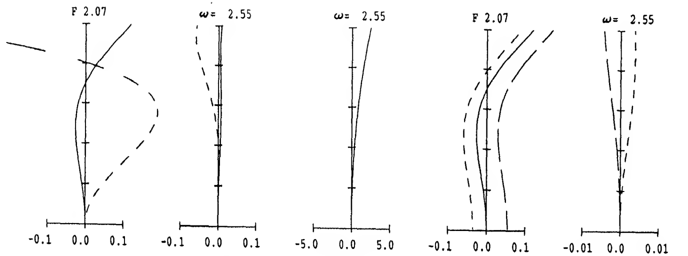


FIG. 68



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 69

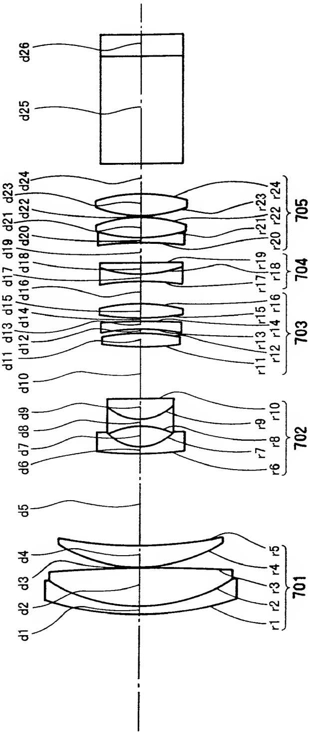

d1 d2 d3 d4 d5 d6 d7 d8 d9 d10 d11 d12 d13 d14 d15 d16 d17 d18 d19 d20 d21 d22 d23 d24 d25 d26
r1 r2 r3 r4 r5 r6 r7 r8 r9 r10 r11 r12 r13 r14 r15 r16 r17 r18 r19 r20 r21 r22 r23 r24
701
702
703
704
705

FIG. 70

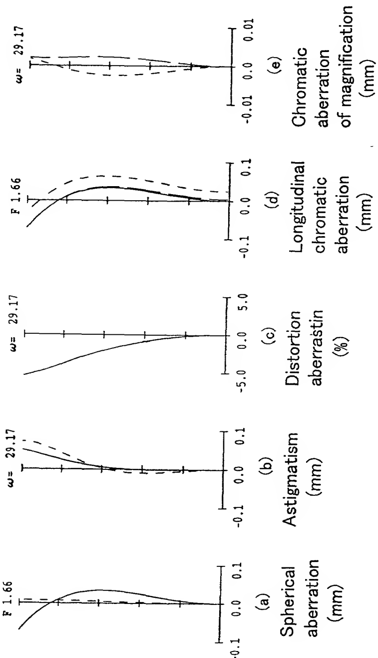

F 1.66
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω= 29.17
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω= 29.17
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.66
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 29.17
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 71

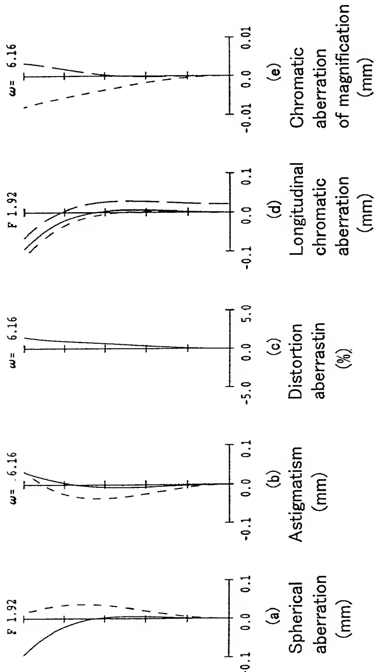

F 1.92
-0.1
0.0
0.1
(a)
Spherical aberration
(mm)
ω= 6.16
-0.1
0.0
0.1
(b)
Astigmatism
(mm)
ω= 6.16
-5.0
0.0
5.0
(c)
Distortion aberrastin
(%)
F 1.92
-0.1
0.0
0.1
(d)
Longitudinal chromatic aberration
(mm)
ω= 6.16
-0.01
0.0
0.01
(e)
Chromatic aberration of magnification
(mm)

FIG. 72

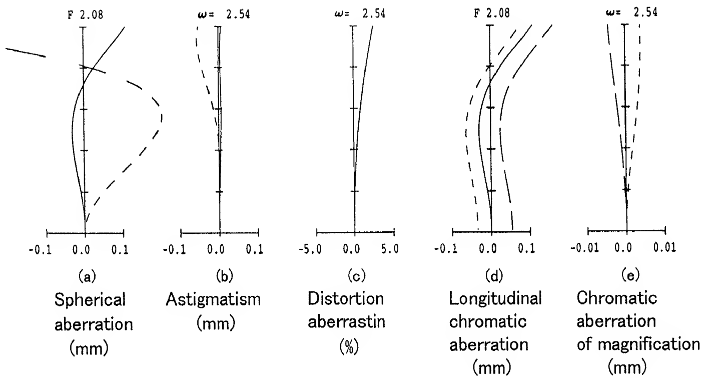

F 2.08
ω= 2.54
ω= 2.54
F 2.08
ω= 2.54
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.01 0.0 0.01
(a)
Spherical aberration (mm)
(b)
Astigmatism (mm)
(c)
Distortion aberrastin (%)
(d)
Longitudinal chromatic aberration (mm)
(e)
Chromatic aberration of magnification (mm)

FIG. 73

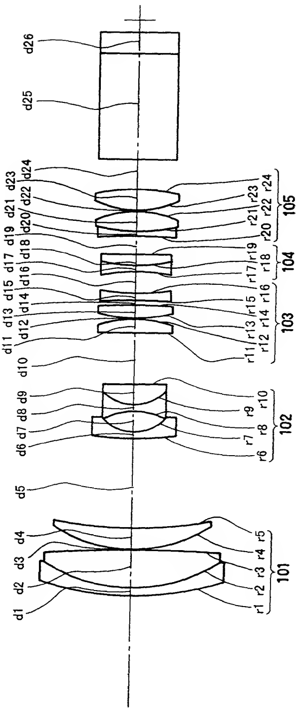
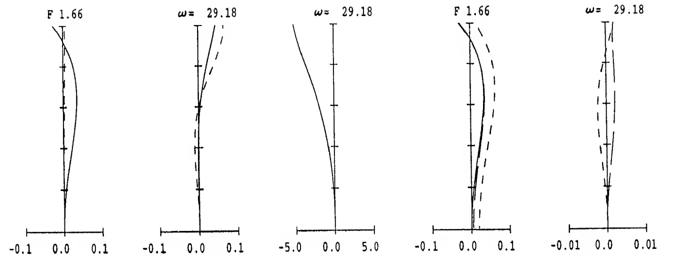

d1 d2 d3 d4 d5 d6 d7 d8 d9 d10 d11 d12 d13 d14 d15 d16 d17 d18 d19 d20 d21 d22 d23 d24 d25 d26
r1 r2 r3 r4 r5 r6 r7 r8 r9 r10 r11 r12 r13 r14 r15 r16 r17 r18 r19 r20 r21 r22 r23 r24
101
102
103
104
105

FIG. 74



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 75

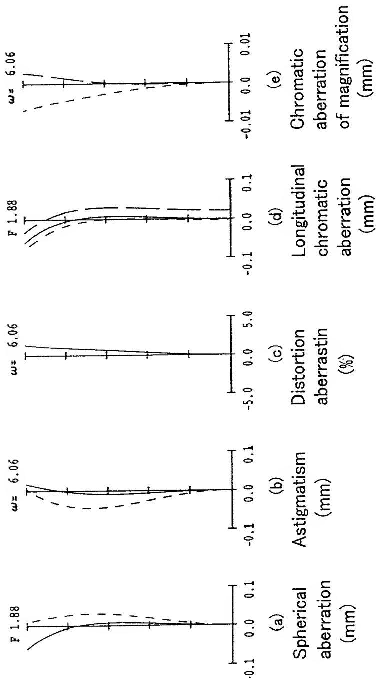

F 1.88
-0.1
0.0
0.1
(a)
Spherical
aberration
(mm)
ω= 6.06
-0.1
0.0
0.1
(b)
Astigmatism
(mm)
ω= 6.06
-5.0
0.0
5.0
(c)
Distortion
aberrastin
(%)
F 1.88
-0.1
0.0
0.1
(d)
Longitudinal
chromatic
aberration
(mm)
ω= 6.06
-0.01
0.0
0.01
(e)
Chromatic
aberration
of magnification
(mm)

FIG. 76

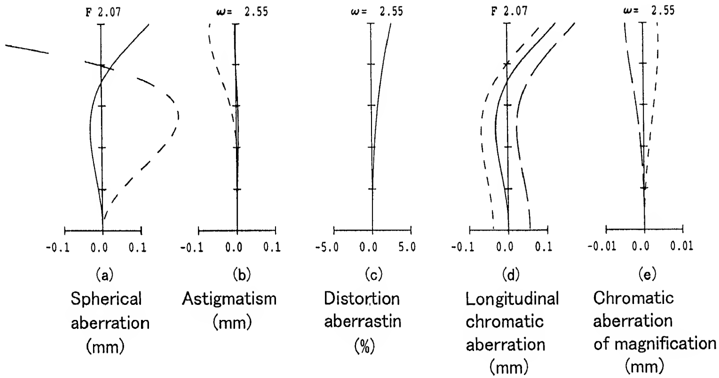

F 2.07
ω= 2.55
ω= 2.55
F 2.07
ω= 2.55
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.01 0.0 0.01
(a) Spherical aberration (mm)
(b) Astigmatism (mm)
(c) Distortion aberrastin (%)
(d) Longitudinal chromatic aberration (mm)
(e) Chromatic aberration of magnification (mm)

FIG. 77

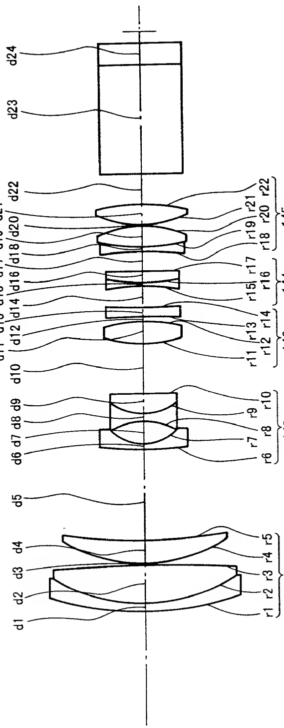

d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
d19
d20
d21
d22
d23
d24
r1
r2
r3
r4
r5
r6
r7
r8
r9
r10
r11
r12
r13
r14
r15
r16
r17
r18
r19
r20
r21
r22
141
142
143
144
145

FIG. 78

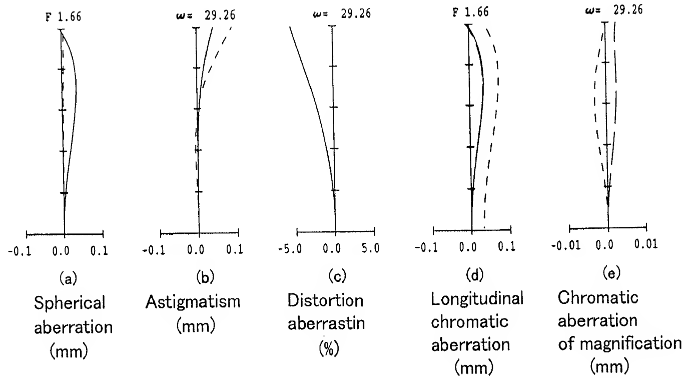
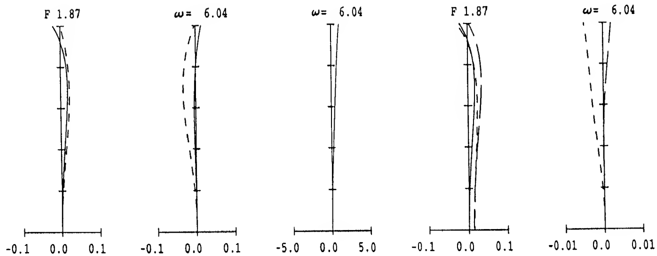

F 1.66
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω= 29.26
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω= 29.26
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.66
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 29.26
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 79



(a) Spherical aberration (mm)

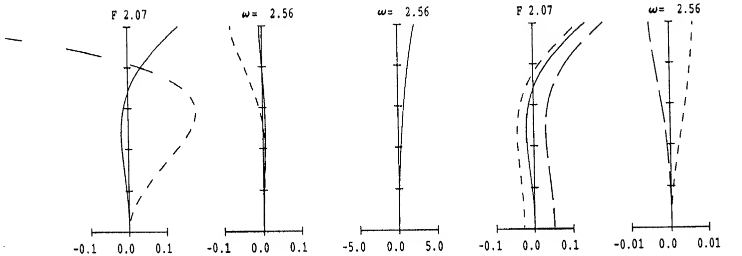
(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 80



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 81

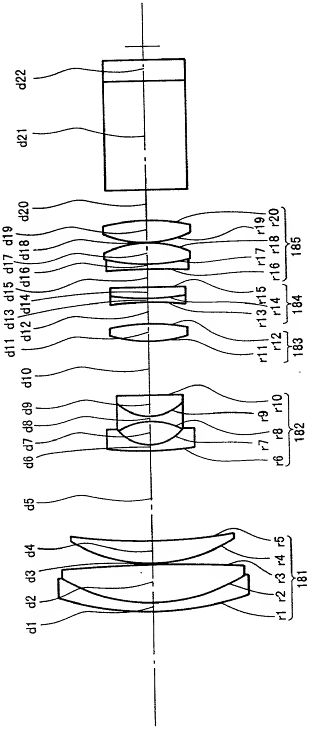
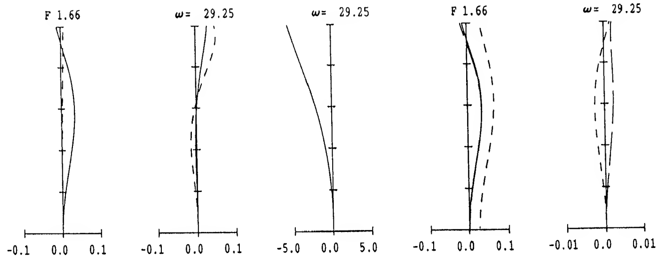

d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
d16
d17
d18
d19
d20
d21
d22
r1
r2
r3
r4
r5
181
r6
r7
r8
r9
r10
182
r11
r12
183
r13
r14
r15
184
r16
r17
r18
r19
r20
185

FIG. 82



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 83

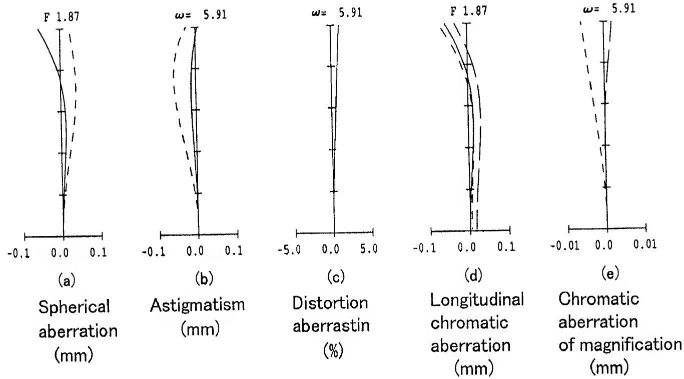

F 1.87
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω= 5.91
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω= 5.91
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 1.87
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 5.91
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 84

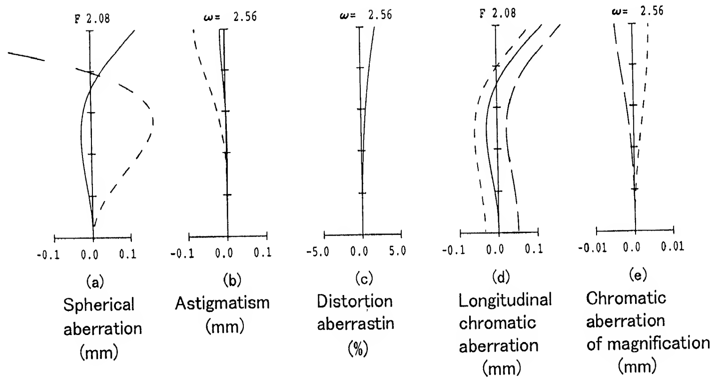

F 2.08
-0.1 0.0 0.1
(a)
Spherical aberration (mm)
ω= 2.56
-0.1 0.0 0.1
(b)
Astigmatism (mm)
ω= 2.56
-5.0 0.0 5.0
(c)
Distortion aberrastin (%)
F 2.08
-0.1 0.0 0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 2.56
-0.01 0.0 0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 85

09/701754

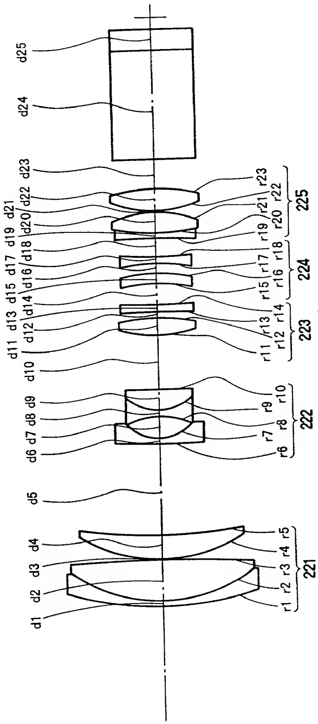


FIG. 86

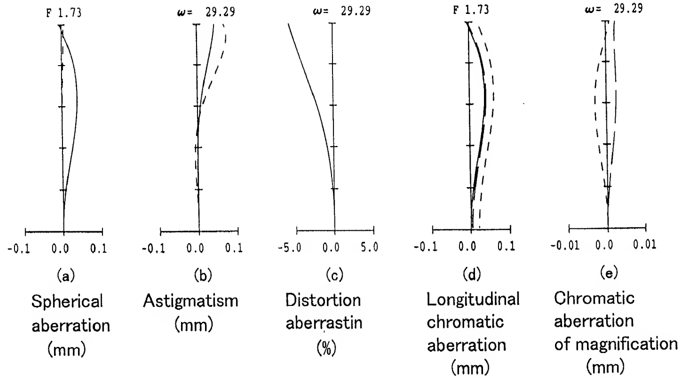

F 1.73
ω= 29.29
ω= 29.29
F 1.73
ω= 29.29
-0.1 0.0 0.1
-0.1 0.0 0.1
-5.0 0.0 5.0
-0.1 0.0 0.1
-0.01 0.0 0.01
(a)
Spherical aberration (mm)
(b)
Astigmatism (mm)
(c)
Distortion aberrastin (%)
(d)
Longitudinal chromatic aberration (mm)
(e)
Chromatic aberration of magnification (mm)

FIG. 87

09/701754

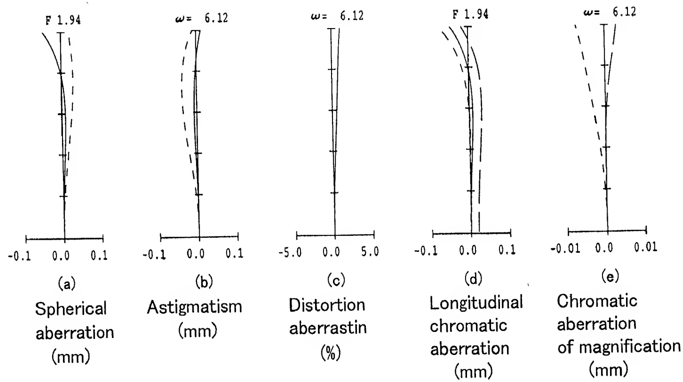
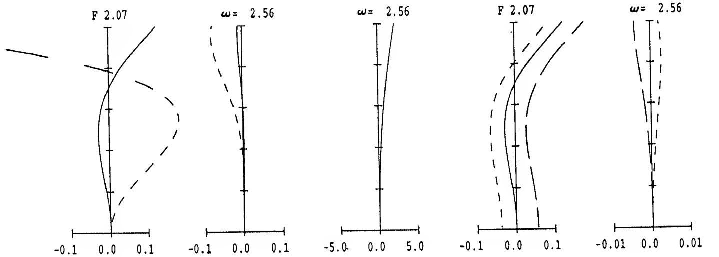


FIG. 88



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 89

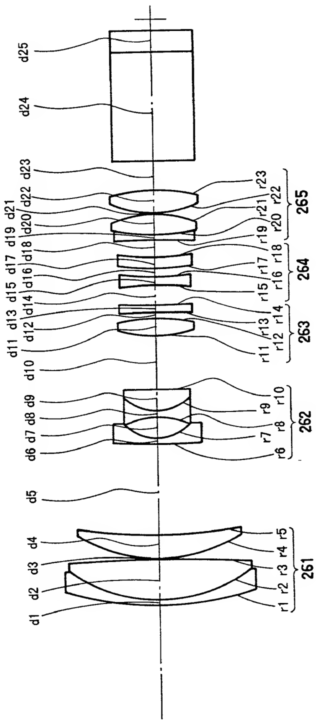

d1 d2 d3 d4 d5 d6 d7 d8 d9 d10 d11 d12 d13 d14 d15 d16 d17 d18 d19 d20 d21 d22 d23 d24 d25
r1 r2 r3 r4 r5
261
r6 r7 r8 r9 r10
262
r11 r12 r13 r14
263
r15 r16 r17 r18
264
r19 r20 r21 r22 r23
265

FIG. 90

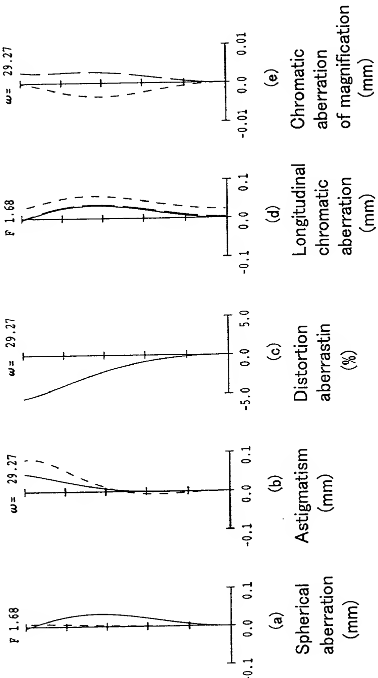
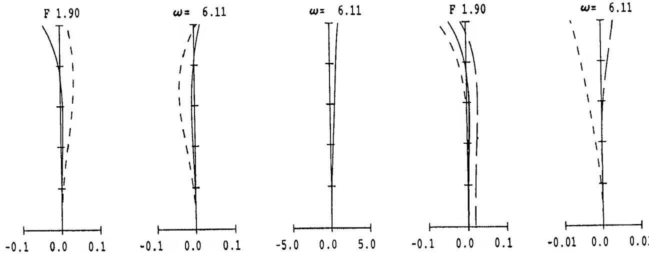

F 1.68
-0.1
0.0
0.1
(a)
Spherical aberration (mm)
ω= 29.27
-0.1
0.0
0.1
(b)
Astigmatism (mm)
ω= 29.27
-5.0
0.0
5.0
(c)
Distortion aberrastin (%)
F 1.68
-0.1
0.0
0.1
(d)
Longitudinal chromatic aberration (mm)
ω= 29.27
-0.01
0.0
0.01
(e)
Chromatic aberration of magnification (mm)

FIG. 91



(a) Spherical aberration (mm)

(b) Astigmatism (mm)

(c) Distortion aberrastin (%)

(d) Longitudinal chromatic aberration (mm)

(e) Chromatic aberration of magnification (mm)

FIG. 92

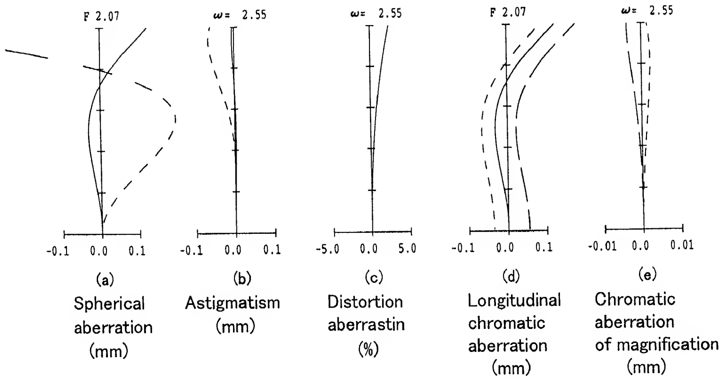
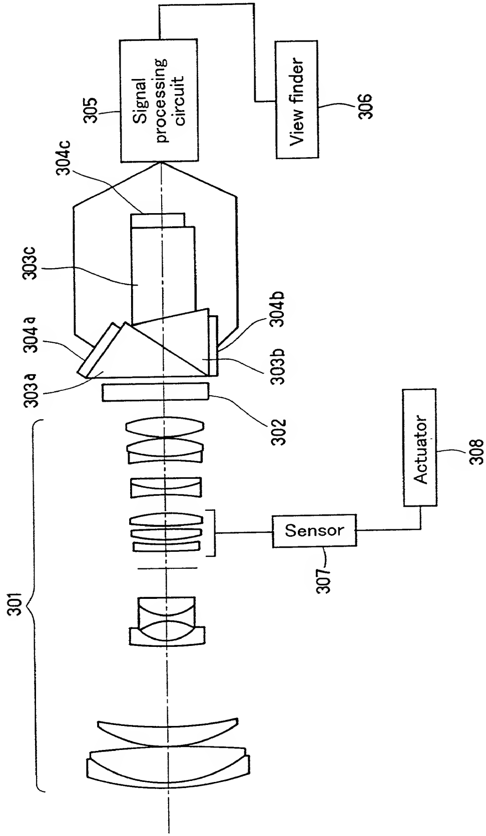


FIG. 93

09/701754



Signal processing circuit
View finder
Sensor
Actuator
301
302
303a
303b
303c
304a
304b
304c
305
306
307
308

FIG. 94

Attorney Docket No. 10873.593USWO

MERCHANT & GOULD P.C.

United States Patent Application

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: ZOOM LENS AND VIDEO CAMERA COMPRISING THE SAME

The specification of which
a. ☐ is attached hereto
b. ☒ was filed on as application serial no. and was amended on (if applicable) (in the case of a PCT-filed application) described and claimed in international no. PCT/JP99/02910 filed May 31, 1999 and as amended on October 7, 1999 and March 16, 2000 (if any), which I have reviewed and for which I solicit a United States patent.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (attached hereto).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed:

a. ☐ no such applications have been filed.
b. ☒ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119

COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)
Japan	10-151361	1 June 1998	
Japan	10-302109	23 October 1998	
Japan	11-108482	15 April 1999	

ALL FOREIGN APPLICATION(S), IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)

COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	DATE OF ISSUE (day, month, year)

I hereby claim the benefit under Title 35, United States Code, § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. APPLICATION NUMBER	DATE OF FILING (day, month, year)	STATUS (patented, pending, abandoned)

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

U.S. PROVISIONAL APPLICATION NUMBER	DATE OF FILING (Day, Month, Year)

I hereby appoint the following attorney(s) and/or patent agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith:

Albrecht, John W.	Reg. No. 40,481
Ali, M. Jeffer	Reg. No. 46,359
Anderson, Gregg I.	Reg. No. 28,828
Batzli, Brian H.	Reg. No. 32,960
Beard, John L.	Reg. No. 27,612
Berns, John M.	Reg. No. 43,496
Black, Bruce E.	Reg. No. 41,622
Branch, John W.	Reg. No. 41,633
Bremer, Dennis C.	Reg. No. 40,528
Bruess, Steven C.	Reg. No. 34,130
Byrne, Linda M.	Reg. No. 32,404
Campbell, Keith	Reg. No.P-46,597
Carlson, Alan G.	Reg. No. 25,959
Caspers, Philip P.	Reg. No. 33,227
Chiapetta, James R.	Reg. No. 39,634
Clifford, John A.	Reg. No. 30,247
Coldren, Richard J	Reg. No 44,084
Daignault, Ronald A.	Reg. No. 25,968
Daley, Dennis R.	Reg. No. 34,994
Dalglish, Leslie E.	Reg. No. 40,579
Daulton, Julie R.	Reg. No. 36,414
DeVries Smith, Katherine M.	Reg. No. 42,157
DiPietro, Mark J.	Reg. No. 28,707
Edell, Robert T.	Reg. No. 20,187
Epp Ryan, Sandra	Reg. No. 39,667
Glance, Robert J.	Reg. No. 40,620
Goggin, Matthew J.	Reg. No. 44,125
Golla, Charles E.	Reg. No. 26,896
Gorman, Alan G.	Reg. No. 38,472
Gould, John D.	Reg. No. 18,223
Gregson, Richard	Reg. No. 41,804
Gresens, John J.	Reg. No. 33,112
Hamer, Samuel A.	Reg. No. 46,754
Hamre, Curtis B.	Reg. No. 29,165
Harrison, Kevin C.	Reg. No.P-46,759
Hertzberg, Brett A.	Reg. No. 42,660
Hillson, Randall A.	Reg. No. 31,838
Holzer, Jr., Richard J.	Reg. No. 42,668
Johnston, Scott W.	Reg. No. 39,721
Kadievitch, Natalie D.	Reg. No. 34,196
Karjeker, Shaukat	Reg. No. 34,049
Kastelic, Joseph M.	Reg. No. 37,160
Kettelberger, Denise	Reg. No. 33,924
Keys, Jeramie J.	Reg. No. 42,724
Knearl, Homer L.	Reg. No. 21,197
Kowalchyk, Alan W.	Reg. No. 31,535
Kowalchyk, Katherine M.	Reg. No. 36,848
Lacy, Paul E.	Reg. No. 38,946
Larson, James A.	Reg. No. 40,443
Leon, Andrew J.	Reg. No. 46,869
Leonard, Christopher J.	Reg. No. 41,940
Liepa, Mara E.	Reg. No. 40,066
Lindquist, Timothy A.	Reg. No. 40,701
Lycke, Lawrence E.	Reg. No. 38,540
McAuley, Steven A.	Reg. No. 46,084
McDonald, Daniel W.	Reg. No. 32,044
McIntyre, Jr., William F.	Reg. No. 44,921
Mitchem, M. Todd	Reg. No. 40,731
Mueller, Douglas P.	Reg. No. 30,300
Nichols, A. Shane	Reg. No. 43,836
Pauly, Daniel M.	Reg. No. 40,123
Phillips, Bryan K.	Reg. No. P-46,990
Phillips, John B.	Reg. No. 37,206
Plunkett, Theodore	Reg. No. 37,209
Prendergast, Paul	Reg. No. 46,068
Pytel, Melissa J.	Reg. No. 41,512
Qualey, Terry	Reg. No. 25,148
Reich, John C.	Reg. No. 37,703
Reiland, Earl D.	Reg. No. 25,767
Samuels, Lisa A.	Reg. No. 43,080
Schmaltz, David G.	Reg. No. 39,828
Schuman, Mark D.	Reg. No. 31,197
Schumann, Michael D.	Reg. No. 30,422
Scull, Timothy B.	Reg. No. 42,137
Sebald, Gregory A.	Reg. No. 33,280
Skoog, Mark T.	Reg. No. 40,178
Spellman, Steven J.	Reg. No. 45,124
Stoll-DeBell, Kirstin L.	Reg. No. 43,164
Sumner, John P.	Reg. No. 29,114
Swenson, Erik G.	Reg. No. 45,147
Tellekson, David K.	Reg. No. 32,314
Trembath, Jon R.	Reg. No. 38,344
Tuchman, Ido	Reg. No. 45,924
Underhill, Albert L.	Reg. No. 27,403
Vandenburgh, J. Derek	Reg. No. 32,179
Wahl, John R.	Reg. No. 33,044
Weaver, Karrie G.	Reg. No. 43,245
Welter, Paul A.	Reg. No. 20,890
Whipps, Brian	Reg. No. 43,261
Whitaker, John E.	Reg. No. 42,222
Wickhem, J. Scot	Reg. No. 41,376
Williams, Douglas J.	Reg. No. 27,054
Withers, James D.	Reg. No. 40,376
Witt, Jonelle	Reg. No. 41,980
Wu, Tong	Reg. No. 43,361
Xu, Min S.	Reg. No. 39,536
Zeuli, Anthony R.	Reg. No. 45,255

I hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/ organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct Merchant & Gould P.C. to the contrary.

Please direct all correspondence in this case to Merchant & Gould P.C. at the address indicated below:

Merchant & Gould P.C.
P.O. Box 2903
Minneapolis, MN 55402-0903

23552
PATENT TRADEMARK OFFICE

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2	**Full Name Of Inventor** 1-00	**Family Name** Yamada	**First Given Name** Katsu	**Second Given Name**
0	**Residence & Citizenship**	**City** Osaka	**State or Foreign Country** Japan	**Country of Citizenship** Japan JPX
1	**Post Office Address**	**Post Office Address** 10-8, Nishiotsuka 1-chome, Matsubara-shi	**City** Osaka	**State & Zip Code/Country** 580-0011 / Japan
Signature of Inventor 201: Katsu Yamada			**Date:** November 10. 2000	

2	**Full Name Of Inventor** 2-00	**Family Name** Ono	**First Given Name** Shusuke	**Second Given Name**
0	**Residence & Citizenship**	**City** Osaka	**State or Foreign Country** Japan	**Country of Citizenship** Japan JPX
2	**Post Office Address**	**Post Office Address** 31-11, Fukazawahonmachi, Takatsuki-shi	**City** Osaka	**State & Zip Code/Country** 569-0033 / Japan
Signature of Inventor 202: Shusuke Ono			**Date:** November 10, 2000	

§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim;

or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.